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OF THE

IRON AND STEEL INSTITUTE

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EDITED BY

BENNETT H. BROUGH

SECRETARY

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THE IRON AND STEEL INSTITUTE.

SECTION I.

MINUTES OF PROCEEDINGS.

ANNUAL GENERAL MEETING.

The ANNUAL GENERAL MEETING of the IRON AND STEEL INSTITUTE was held at the Institution of Civil Engineers, Great George Street, London, on Wednesday, May 9, 1900—Sir WILLIAM ROBERTS-AUSTEN, K.C.B., D.C.L., F.R.S., President, in the chair.

The SECRETARY read the minutes of the last meeting, held at the Town Hall, Manchester, on August 15 and 16, 1899, which were confirmed and signed.

Mr. John Hardisty and Mr. F. S. Warburg were appointed scrutineers, and, on the completion of their scrutiny, reported that the following gentlemen had been duly elected as members of the Institute:—

NAME.	ADDRESS.	PROPOSERS.
Baker, Sir Benjamin, K.C.M.G., LL.D., F.R.S., <i>Past-President</i> Inst. C.E., M.I. Mech. E.	2 Queen Square Place, Westminster, London, S.W.	Sir Lowthian Bell, Sir William C. Roberts-Austen, Sir David Dale.
Barclay, George	Vulcan Works, Paisley, N.B.	Sir William Arrol, Andrew Stewart, John C. Tannett.

NAME.	ADDRESS.	PROPOSERS.
Beilby, George, F.I.C.	St. Kitts, Slateford, Scotland	Sir William C. Roberts-Austen, Edward P. Martin, Sir William T. Lewis.
Colby, Albert Ladd .	Bethlehem Steel Company, So. Bethlehem, Pennsylvania, U.S.A.	J. Fritz Abram S. Hewitt, Henry M. Howe.
Danks, Frederick Thomas	Glengarth, Quinton, near Birmingham	Arthur Keen, E. Windsor Richards, Arthur Cooper.
Davenport, Frank . .	13 Trafford Road, Salford	J. Slater Lewis, Henry Webb, Thomas Addyman.
Dellwik, Carl . . .	38 Arcade Chambers, St. Mary's Gate, Manchester	Tom Bergendal, Walter R. Hay, C. J. A. Isakson.
Dickinson, John . .	Green Bank, Ulverston, Lancashire	Myles Kennedy, Frank S. Ainslie, George J. Snelus.
Dory, Alphonse . . .	Bilbao, Spain	Ramon de la Sota, Luis M. de Aznar, Eduardo de Aznar.
Foster, Henry . . .	Knott Mill Iron Works, Manchester	John W. Spencer, T. W. Hogg, Thomas Ashbury.
Fullerton, Alexander	Vulcan Works, Paisley, N.B.	Sir William Arrol, Andrew Stewart, John C. Tannett.
Gillhausen, G. . . .	Bachstrasse, Essen-am-Ruhr	Sir David Dale, Edward P. Martin, August Reichwald.
Girvan, Hugh . . .	Maryhill Iron Works, Glasgow	Sir Lowthian Bell, James Riley, Thomas Campbell.
Hall, Thomas Bernard, Assoc. M.Inst. C.E., M.I.Mech.E.	119 Colmore Row, Birmingham	Alfred Muir, Sir T. Salter Payne, Arthur Keen.
Hanson, Weldon . .	Fairleigh, Norton, Stockton-on-Tees	C. Lowthian Bell, Greville T. Jones, W. L. Johnson.
Hill, William . . .	Apedale, Newcastle, Staffordshire	George A. Millward, Herbert Pilkington, Edwin Tonks.
Hodgart, John . . .	Vulcan Works, Paisley, N.B.	Sir William Arrol, Andrew Stewart, John C. Tannett.
Horner, John Stuart, M.A. Assoc. R.S.M.	Feltham Lodge, Surbiton	Sir William C. Roberts-Austen, Edward P. Martin, William Whitwell.
Jardine, Adam . . .	Coats Iron and Steel Works, Coatbridge, N.B.	George Garrett, Andrew Lamberton, William Wylie.
Johnston, Edmund E.	Ashland, Wisconsin, U.S.A.	R. A. Hadfield, A. G. M. Jack, Isaac B. Milne.
Kennedy, John Stuart	Stanhope, New Jersey, U.S.A.	H. H. Campbell, Andrew S. McCreath, James Gayley.
List, Paul	Askam-in-Furness	R. Heath, G. Mure Ritchie, Geo. J. Mair.
MacLay, David M., jun.	3 Woodlands Terrace, Glasgow	David Colville, James Riley, Sir William Arrol.

NAME.	ADDRESS.	PROPOSERS.
Martin, Simon S.	Sparrow's Point, Maryland, U.S.A.	Henry M. Howe, H. H. Campbell, Alfred E. Jessup.
Nesbit, David Mein, M.I.Mech.E.	c/o Ashwell & Nesbit, Ltd., 12 Great James Street, Bedford Row, London, W.C.	Henry Webb, Samuel H. Brooks, Thomas Ashbury.
Patterson, P. C. . .	National Tube Com- pany, McKeesport, Pa., U.S.A.	A. Hennin, W. E. Corey, E. F. Wood.
Pearson, George Frederick	16 Regent Road, Birk- dale, Lancashire	W. H. Bleckly, W. H. Hew- lett, J. J. Bleckly.
Pearson, Henry Wil- liam, M.Inst.C.E., M.I.Mech.E., F.G.S.	Bristol Waterworks, Bristol	W. H. Maw, Charles D. Philips, Alfred Muir.
Pehrson, Erland Victor	Bofors Steel Works, Bofors, Sweden	C. Danielsson, August Her- lenius, J. C:son Kjellberg.
Porter, Holbrook, F.J.	Bethlehem Steel Co., South Bethlehem, Pa., U.S.A.	R. A. Hadfield, Thomas Ashbury, J. E. Stead.
Pye - Smith, Arnold Stanley	27 Park Hill Rise, Croydon, Surrey	William Whitwell, George R. Dunell, Samuel Osborn.
Ritchie, Alexander .	4 Upper Thames Street, London, E.C.	Samuel L. Dore, William Jacks, G. Mure Ritchie.
Rose, Baron	The Mount, Halesowen	Alex. E. Tucker, Sir Ben- jamin Hingley, A. W. Hickman.
Ross, James Russell .	38 Chapel Terrace, Parkhead, Glasgow	Alex. Turnbull, Geo. Garrett, Andrew Graham Service.
Row, Oliver Matthews, M.I.Mech.E.	Dulham Works, Great Bridgewater Street, Manchester	Henry Webb, Samuel Mel- ling, J. F. L. Crosland.
Sahlin, Axel	Millom, Cumberland	Arthur Keen, E. Windsor Richards, David Evans.
Sims, David Thomas .	Neath, Glamorganshire	W. Morris, R. Roberts, M. G. Roberts.
Stanbury, George . .	2 White Lion Court, Cornhill, London, E.C.	James Riley, H. J. Cornish, J. T. Milton.
Stanley, Edward . .	Clarence Iron Works, Middlesbrough	Sir Lowthian Bell, Edward P. Martin, Sir William T. Lewis.
Storey, William Ed- ward	Empress Foundry, Corn- brook, Manchester	Sir Benjamin Hingley, Sir Alfred Hickman, S. Dickinson.
Tack, Lucien . . .	2 Rue Désiré Ruggieri, Paris	William Tozer, Herbert Bar- ber, G. G. Coppel.
Tennent, John . . .	Bredenhill, Bothwell, N.B.	James Riley, James Kerr, John R. Cross
Thal, Christian de .	32 Moika, St. Peters- burg	A. Greiner, John D. Ellis, James Riley.

ELECTION OF MEMBERS.

NAME.	ADDRESS.	PROPOSERS.
Tosh, Edmund Logan	Cambrian Place, Ulverston, Lancashire	Myles Kennedy, Frank S. Ainslie, George J. Snelus.
Vaughan, Henry . .	Standard Works, Willenhall, Staffordshire	George North Adams, William Thomas, Chas. Harry Page.
Wallwork, Roughsedge, M.I. Mech. E.	c/o H. Wallwork & Co., Roger Street, Manchester	Joseph Adamson, Henry Webb, Thomas Ashbury.
Watson, John Stanley	7 Ashmount, Broomhill, Sheffield	R. A. Hadfield, William Tozer, G. G. Coppel.
Whitehouse, William Henry	Bryn Aur, Gold Tops, Newport, Monmouthshire	Arthur Keen, E. Windsor Richards, David Evans.

The SECRETARY then read the following Report of the Council upon the proceedings of the Institute during the year 1899 :—

REPORT OF COUNCIL.

At this thirty-first Annual General Meeting of the Iron and Steel Institute, the Council have the pleasure of presenting to the members their Report on the proceedings of the Institute during the year 1899. In doing so, they are glad to be able to state that the prosperity of the Institute recorded in their last Report has been more than maintained during the past year.

THE ROLL OF THE INSTITUTE.

During the year under review there have been added to the register 110 names, the average annual number for the past six years being 86. The number of members on the roll of the Institute on December 31, 1899, was—

Honorary members	.	.	.	.	.	8
Life members	.	.	.	.	.	14
Ordinary members	.	.	.	.	.	1556
Total	.	.	.	.	.	<u>1578</u>

The Council have to congratulate several members of the Institute who have had high distinctions conferred upon them. In connection with the visit of the Institute to Stockholm, the King of Sweden was pleased to create Mr. E. P. Martin, Past-President, a Knight Commander of the Royal Order of Wasa. Mr. R. A. Hadfield, Member of Council, has been elected Master Cutler of Sheffield. Mr. T. Drew-Bear has been appointed by the King of the Belgians a Knight of the Order of Leopold. The German Emperor has conferred upon Mr. H. Brauns and Mr. E. Schrödter, Secretary of the Society of German Ironmasters, the Order of the Red Eagle. Mr. F. Baare has been accorded the title of Kommerzienrath, and Mr. H. Lueg has received the honorary freedom of the town of Oberhausen. The Imperial Russian Order of St. Stanislaus has been conferred upon Dr. H. Wedding, Honorary Member and Bessemer Gold Medallist. The King of Sweden has created Captain

G. Dyrssen, Minister of Marine, a Knight Commander of the Royal Order of the Sword, Mr. I. A. Brinell a Knight of the Royal Order of the Northern Star, and Mr. T. Magnuson and Mr. Bennett H. Brough, the Secretary of the Institute, Knights of the Royal Order of Wasa. The Council of the Institution of Civil Engineers have awarded premiums for original communications to Sir William Roberts-Austen, President, Mr. Hadfield, Member of Council, Mr. A. P. Head, and Mr. F. Osmond.

On the occasion of the centenary of the Franklin Institute of Philadelphia, Mr. Abram S. Hewitt and Mr. John Fritz, Honorary Members of the Iron and Steel Institute, and Mr. C. Kirchhoff, who acted as Secretary of the Reception Committee for the American Meeting of the Iron and Steel Institute, were elected Honorary Members. Mr. C. H. Morgan has been elected President of the American Society of Mechanical Engineers.

During the year 1899 the Institute has suffered great losses by the death of the following twenty-six members :—

Allen, Harry (Sheffield)	February 23.
Bowser, Howard (Glasgow)	September 8.
Durfee, William Franklin (New York)	November 14.
Farley, Reuben (West Bromwich)	March 11.
Foster, William Orme (Stourbridge)	September 29.
Frew, John (Carron, N.B.)	August 26.
Galton, Sir Douglas (London)	March 10.
Hanson, William (Middlesbrough)	May 6.
Head, Jeremiah (London)	March 10.
Hunt, Alfred Ephraim (Pittsburg)	April 26.
Hutton, Robert (Whithy)	January 25.
Jackson, John (Chesterfield)	February 28.
Kennedy, William (Glasgow)	May 20.
Mayer, Ernest (Paris)	December 9.
Naylor, John William (Leeds)	June 4.
Needham, John (Manchester)	October 18.
Ogle, Richard (Manchester)	January 2.
Pattison, John (Naples)	November.
Ryland, Frederick (West Bromwich)	February 11.
Simon, Henry (Manchester)	July 22.
Thomson, J. Mann (Glasgow)	March 12.
Tosh, Edmund G. (Ulverston)	April 22.

Warburg, Frederick Elias (London)	. . .	February 9.
Wheatcroft, Ernest (Sheffield)	. . .	June.
Wigzell, Eustace (Sowerby Bridge)	. . .	October 2.
Williams, Nicholas (Millom)	. . .	February 11.
Young, Robert (London)	. . .	January 3.

The following two deaths of members occurred in 1898, but were not noted in the Council Report for that year :—

Patchett, George (Halifax)	. . . . .	April 10.
Whitehead, John (Buxton)	. . . . .	April 16.

Of the deceased members, Mr. A. E. Hunt was an energetic member of the Central Committee that organised the visit of the Institute to America in 1890. Mr. Jeremiah Head, one of the original members of the Institute, contributed no less than seven papers to its proceedings, and Mr. Henry Simon also contributed several important papers. Particulars of the professional careers of the deceased members will be found in the obituary notices published in the Journal of the Institute.

In consequence of the non-payment of subscriptions, the names of five members have been removed from the list, and there have been twenty-one resignations of membership.

FINANCE.

The Statement of Accounts for the year 1899 is now submitted to the members by the Honorary Treasurer. It will be observed that the income for the year amounted to £4322, 10s. 4d., and the expenditure to £3606, 16s. 6d.

The corresponding figures for recent years were as follows :—

	Income.			Expenditure.		
	£	s.	d.	£	s.	d.
1893 . . .	3589	11	0	3899	15	2
1894 . . .	3749	3	3	3074	1	9
1895 . . .	4159	7	5	3088	6	7
1896 . . .	3891	12	11	4338	14	11
1897 . . .	3937	5	8	3207	10	3
1898 . . .	3985	13	7	3989	16	8
Average	3885	8	11	3599	14	3

An addition has been made to the invested funds of the Institute by the purchase of £700 Middlesbrough Corporation Water Works 3½ per cent. Debenture Stock.

MEETINGS.

During the year under review two Meetings were held as usual. The Annual Meeting was held at the Institution of Civil Engineers, whose courtesy in providing accommodation and other facilities for this purpose for many years past demands grateful acknowledgment.

The Autumn Meeting, held, for the third time since the foundation of the Institute, at Manchester, was very largely attended, and was brilliantly successful. A very representative and influential Reception Committee was formed, with the Lord Mayor of Manchester (W. H. Vaudry, Esq.) acting as President, Mr. Samuel R. Platt, Vice-President, as Chairman, Mr. Henry Webb as Vice-Chairman, and Mr. Thomas Ashbury as Honorary Secretary. Lavish hospitality was dispensed, and the grateful thanks of the Members were accorded for the unbounded cordiality of the reception given to the Institute.

To Mr. Thomas Ashbury, who undertook the duties of Honorary Secretary of the Reception Committee, the Council have expressed on behalf of the Members their sense of indebtedness by presenting to him a silver tea and coffee service with a suitable inscription, in appreciation of his valuable services in carrying out the necessary arrangements for the Manchester Meeting.

The titles of the papers contributed to the Institute's proceedings during the year were as follows :—

1. On the Gellivare Iron Ore Mines. By H. BAUERMAN.
2. On Tilting Open-Hearth Furnaces. By A. P. HEAD.
3. On an Improved Dipping-Needle. By H. LOUIS.
4. On the Diffusion of Elements in Iron. By J. O. ARNOLD and A. M'WILLIAM.
5. On the Use of Blast-Furnace and Coke-Oven Gases. By E. DISDIER.
6. On the Theories and Facts relating to Cast Iron and Steel. By B. S. SUMMERS.
7. On the Manufacture of Steel direct from the Ore in the Blast-Furnace. By D. TSCHERNOFF.
8. On the Use of Hot-Blast in the Bessemer Process. By J. WIBORGH.
9. On the Solution Theory of Iron and Steel. By the Baron JÜPTNER VON JONSTORFF.

10. On the Use of Finely Divided Iron Ore obtained by Concentrating. By J. WIBORGH.
11. On Some Forms of Magnetic Separators, and their Application to Different Ores. By H. C. McNEILL.
12. On a New Casting Machine for Blast-Furnaces. By R. H. WAINFORD.
13. On the Iron Industry in the Territory of His Highness the Nizam of Hyderabad, Deccan. By SYED ALI BILGRAMI.
14. On India as a Centre for Steel Manufacture. By Major R. H. MAHON.
15. On Practical Microscopic Analysis for Use in the Steel Industries, with an Introduction to a Systematic Study of Soft and Dead-Soft Steel. By C. H. RIDSDALE.
16. On Pig-Iron Fractures and their Value in Foundry Practice. By J. W. MILLER.
17. On the Present Position of the Solution Theory of Carburised Iron. By A. STANSFIELD.
18. On the Relation between the Structure of Steel and its Thermal and Mechanical Treatment. By A. SAUVEUR.
19. On the Constitution of Steel. By E. D. CAMPBELL.

The Annual Dinner of the members of the Institute was held on Thursday, May 4th, at the Hotel Cecil. The chair was occupied by the President, and amongst the noblemen and gentlemen who accepted invitations were His Excellency the Swedish and Norwegian Minister, Lord Lister, P.R.S., Lord Claud Hamilton, the Bishop of Rochester, Lord Strathcona and Mount Royal, G.C.M.G., Lord Welby, G.C.B., the Honourable Sir Charles Fremantle, K.C.B., the Honourable E. Lyulph Stanley, Sir Frederick Bramwell, Bart., F.R.S., the Presidents of many of the kindred societies, and a large number of members and their friends.

PUBLICATIONS.

Two volumes of the Journal of the Institute have been published, containing together 1082 pages of letterpress and 36 plates. In addition to the papers read before the Institute, and the discussion and correspondence relating to them, those volumes contain 1337 abstracts of papers relating to iron and steel and kindred subjects published in other home and foreign technical Journals and Transactions.

LIBRARY.

Numerous presentations to the Library have been made, a list of which is given in the Journal of the Institute. For these the Council record their grateful thanks to the several donors. Members who have published works valuable for reference, or pamphlets on subjects relating to iron and steel, of which they could present copies, are reminded that such contributions to the Library are highly acceptable for permanent preservation. The collection of portraits has been enriched by the presentation, by Messrs. Maull & Fox, of a number of platinotype photographs of members of the Institute.

BESSEMER MEDAL.

In obedience to a command from Her Majesty the Queen, the President, the immediate Past-President (Mr. E. P. Martin), Sir Lowthian Bell, Past-President, and the Secretary proceeded to Windsor on July 18. The deputation was introduced by the Earl of Clarendon, the Lord in Waiting, and the President offered to Her Majesty an illuminated address and the Bessemer Gold Medal in commemoration of the progress made in the metallurgy of iron during Her Majesty's reign. The Queen, in intimating the interest with which Her Majesty was pleased to accept the medal, made a gracious reply to the address.

ROYAL CHARTER OF INCORPORATION.

It having been determined that it would be for the advantage of the Institute to obtain incorporation under a Royal Charter, a petition was addressed, on behalf of himself and the other members of the Iron and Steel Institute, to Her Majesty in Council by Mr. Edward Pritchard Martin (President, 1897-99); and the Royal Assent having been obtained, the Institute was duly incorporated under a Royal Charter.

APPOINTMENT OF REPRESENTATIVES.

The President and Sir Frederick Abel, Past-President, were appointed representatives of the Institute on the governing body of the National Physical Laboratory, and the President continued to represent the Institute on the governing body of the Imperial Institute. During the year, Sir Lowthian Bell, Past-President, Mr. E. Windsor Richards, Past-President, and Mr. E. P. Martin, Past-President, who, as recorded in the Council Report for 1896, were appointed mem-

bers of a Departmental Committee of the Board of Trade, continued their inquiry as to the extent of the loss of strength in steel rails produced by their prolonged use on railways, and their report will shortly be published. The Institute was also represented on the occasion of the celebration of the fiftieth anniversary of the Society of Austrian Engineers on March 18 by the Secretary, who presented a congratulatory address, in which reference was made to the hospitable reception accorded to the Institute by that Society in 1882.

RETIRING MEMBERS OF COUNCIL.

The election of Sir William Roberts-Austen to the Presidency created a vacancy among the Vice-Presidents, which was filled by the election of Mr. S. R. Platt, and Mr. George Ainsworth was elected a Member of Council to fill the vacancy thus caused.

In accordance with the terms of the Royal Charter of Incorporation, the Council, all of whom are eligible, offer themselves for election. No other candidates have been nominated.

The Hon. Treasurer (Mr. William Whitwell), then read the Statement of Accounts for the year 1899, as follows:—

STATEMENT OF ACCOUNTS.

THE IRON AND STEEL INSTITUTE.

ACCOUNT OF INCOME AND EXPENDITURE FOR THE YEAR ENDED DECEMBER 31, 1889.

INCOME.		EXPENDITURE.	
To Entrance Fees	£ 226 16 0	By Salaries	£1,182 17 6
" Subscriptions	3,341 2 0	" Office Rent, Cleaning, &c.	254 16 9
" Life-Compositions	189 0 0	" Library Books and Binding	52 8 11
" Journal Sales	239 19 6	" Office Furniture	1 2 9
" Interest on Investments	310 3 2	" Annual Meeting Expenses (London)	53 9 7
" Bessemer Medal Fund Interest	15 9 8	" Autumn Meeting Expenses (Manchester)	214 18 2
		" Journal Publishing Expenses:—	
		Printing	£805 11 6
		Ab-tracts	175 0 0
		Translation of Papers	28 10 6
		Postage	82 3 4
			1,091 5 4
		" Postage and Receipt Stamps	94 1 0
		" Printing and Stationery	278 19 11
		" Insurance	1 15 0
		" Bessemer Medal	15 7 6
		" Corporation Duty	14 18 0
		" Sundry Payments, including Expenses of obtaining Charter	240 11 1
		" Auditor's Fee	10 10 0
			3,606 16 6
		" Excess of Income over Expenditure	715 13 10
			£4,322 10 4

STATEMENT OF ACCOUNTS.

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BALANCE SHEET, DECEMBER 31, 1899.

LIABILITIES.		ASSETS.	
To Sundry Creditors:—		By Subscriptions in arrear for 1899, since received	
" Printing Journal	£374 13 0	" Subscriptions in arrear for 1898, since received	£86 2 0
" Postages	39 15 3	" Interest on Investments accrued, due at 31st December 1899	157 4 2
" Library Books	5 4 11	" Journal Sales, since received	88 10 0
" Printing and Stationery	17 11 6	" Cash at Bank	296 6 9
	£437 4 8	" Do. in hands of Secretary	200 0 0
" Subscriptions received in advance	37 16 0		496 6 9
" Iron and Steel Institute Capital Account at 1st January 1899	£396 18 5		
Add Excess of Income over Expenditure transferred from Income and Expenditure Account	715 13 10		
	£1,112 12 3		
Less Purchase of £700 Middlesbrough Corporation Waterworks 3½ per cent. Debenture Stock at 100½	751 2 0		
	£361 10 3		
	£836 10 11		£836 10 11

INVESTED FUNDS OF THE INSTITUTE.

£25,744 North-Eastern Railway 4 per cent. Preference Stock, purchased at a cost of	£4,207 6 7
£788 North-Eastern Railway 4 per cent. Guaranteed Stock, purchased at a cost of	1,008 14 0
£1,546* Beinde, Punjab, and Delhi 5 per cent. Stock, purchased at a cost of	1,999 0 7
£750 Great Indian Peninsula Railway 5 per cent. Stock, purchased at a cost of	1,267 6 0
£700 Middlesbrough Corporation Waterworks 3½ per cent. Debenture Stock, purchased at a cost of	751 2 0
	£9,323 9 2

* This has since been compulsorily converted into "B" annuities of £78, 4s. 5½., expiring 1958, with a Sinking Fund to replace the amount of Stock.

(Signed) WILLIAM WHITWELL, *Hon. Treasurer.*
BENNETT H. BROUGH, *Secretary.*

I have examined the above Accounts with the Books and Vouchers of the Institute, and certify them to be correct. I have also verified the Balance of the Bankers' Account, and examined the Securities for the Invested Funds as shown above.

(Signed) W. B. KEEN,
Chartered Accountant.

3 CHURCH COURT, OLD JEWRY, E.C., May 8, 1899.

BESSEMER MEDAL FUND.

£584 London and North-Western Railway 3 per cent. Debenture Stock.

The PRESIDENT said it was now his duty to move that the Report of the Council and Statement of Accounts be adopted, and in doing so he would make a very few remarks. He would remind the meeting that the year 1899 had been the most successful on record. The receipts were greater than they ever had been before, and, compared with the average for the last six years, the extra expenditure was only £7, notwithstanding the cost of the charter. With reference to that charter he would point out, that it actually added to their dignity as a body, and to their usefulness; but although he happened to be first President under the charter, they owed it mainly to his predecessor, Mr. Martin, and to Sir David Dale, to whom their best thanks were due. The sales of the Journal to the public had been most gratifying, and he thought that fact showed an increased interest in their proceedings was taken outside, as indeed could hardly have been otherwise in view of the important papers published in their Journal. The question of the office accommodation, he ought to have mentioned, had occupied the attention of the Council, and the facilities for work had been greatly improved. Another room had been added, the electric light was being introduced, and generally every effort was being made to make the office more suitable and more comfortable than it had hitherto been to the members of the Institute and to the officers. Then turning to another matter, arrangements had been made to hold the Autumn Meeting in Paris, and he would mention that the date would be the 18th September, and not the 9th, as previously announced, the 18th having been found to be more suitable for their entertainers in Paris, and it would also enable members of the Institute to attend the meeting of the British Association in Bradford, if they wished to do so. He moved that the Report and Statement of Accounts be adopted.

Sir LOWTHIAN BELL, Bart., Past-President, in seconding the motion, said that the success of the Institute, both financially and technically, had been so gratifying that he had no hesitation in seconding the adoption of the Report.

Sir THOMAS WRIGHTSON, Bart., M.P., said that he had now to propose on behalf of the members of the Institute that a vote of

thanks be accorded to the President and Council for their services during the past year. It was a great pleasure to him to have to propose this vote, not only as being one of the original members of the Iron and Steel Institute, but also as being personally known, he believed, to every member of the Council, and more especially to their President, Sir William Roberts-Austen. He thought that the Report which had been read by the Secretary showed that their Institution was in a most excellent position, not only as regards numbers, but also as regards finance. The Treasurer's Report showed that their subscription list during the past year had been higher than in any previous year, and also that the number of members had increased more than in any preceding year. He thought he had noticed that the membership had increased 110 during the last year as compared with 86 in the previous year. This all proved that their Institute was in a very flourishing condition, and he thought that this prosperity made them recognise more than ever the efficiency of the Council, headed by the President, and that it was owing to their exertions that they had attained the position they at present occupied. The Iron and Steel Institute was peculiar as being an industrial body walking hand in hand with science. They all knew the enormous strides that had been made in science during the past century, but it was to the Iron and Steel Institute that they looked as an illustration of the extraordinary progress that might be made when science and industry went hand in hand. They also had the advantage at the present time of great commercial prosperity in the different branches of the iron and steel trade. They all more or less participated in this, and yet at the same time even this prosperity had its lessons. There was very little doubt that trade would again become depressed, and when that occurred, the best authorities told them that they would have very keen competition from the other side of the Atlantic. It depended largely upon the way in which they spent the resources which they were at present obtaining, and upon the judicious way in which they treated their revenues that were coming in, as to whether they would be able to hold their own against that keen competition. Those who anticipated the inevitable, and spent the money that they were now making in remodelling their works, and in pre-

paring themselves for the struggle which was assuredly going to take place, would be the survivors, because they were the fittest. He trusted that they would not forget in this present year of prosperity that it had its lessons, and that it depended upon the way in which they took those lessons whether they would be able to maintain their position hereafter. He thought they had in their President one who had worthily so far maintained the position of their Institution. He had known Sir William Roberts-Austen for many years, and he had had many opportunities of observing his scientific abilities, and he believed that the Institute would benefit very largely by his Presidency. Finally, he had very much pleasure in seconding the motion that they accord to him and to the members of the Council a vote of thanks for the excellent way in which they had managed the affairs of their Institution for the past year.

Mr. HENRY WEBB (Bury, Lancashire) said he esteemed it a privilege to have the honour of seconding the vote so ably proposed by Sir Thomas Wrightson, M.P. He had just told them of the progress that the Institute had made during the past year, and all of it was owing to the ability, the energy, and the loving devotion that the President, Vice-Presidents, and Council had given to the work of the Institute. The proposer had also hinted at the progress the Institute had made during a long period, and Sir Thomas Wrightson had the honour of being one of the original members. He (the speaker) was sorry that he could not lay claim to that honour, but he had been a member now for twenty-seven years, and if any one cared to compare the Institute of that period with the present time, it was easy to see what vast strides had been made. If he were permitted for one moment he would tell them two things that during that period had impressed him very much. One was the great work that the Institute had done in breaking down what he might be permitted to call the spirit of selfishness amongst employers in the iron and steel trade, and in substituting for it an open, generous brotherhood. When he was a young man, almost every works was a "sealed book;" there was no admittance; and if any one wanted information, he was met with an amused, cynical smile, as much as to say, "Don't you wish you may get it." But since

then a change had come over the scene; and he did not think that any one had benefited more by the free, open intercourse which had been established than their friends in America. In the early days of the Institute their unbounded natural resources and wealth were but very little known, but the works in this country, with its accumulated experience, were open to them, and many of those present would remember how they came over in great numbers and profited by that experience; and they would have to admit now that, building upon the experience of Englishmen, the Americans had "gone one better," and that they on this side of the Atlantic had now something to learn from them. But the Americans had heartily reciprocated the generosity of this country, for whenever we visited them, they opened their works most generously, and everything was shown that one could desire to see. Another thing that struck him during this period was that the Institute had never lacked the very finest talent of the country to be its Presidents. He would not enumerate them, as it was many years since he had joined the Institute, but he thought most of the Presidents would compare most favourably with those of any other institution. They had had men of great ability, of great scientific attainments, and of great commercial knowledge, who had successfully presided over them year by year, and none had filled the chair more worthily than the President, Sir William Roberts-Austen. Those present would agree with him that their very hearty thanks were due to the President, the Vice-Presidents, and the Council, for the ability, energy, and devotion that they had given to their work, and he wished heartily to second the resolution.

The vote was put to the meeting and enthusiastically carried.

The PRESIDENT said that, in view of the amount of business that had to be got through that day, his expression of thanks would be made very short, although it would be none the less sincere on that account. The one great privilege of a President was that he saw what a large amount of work the Council did, and indeed he had been astonished not only at the amount of work which fell upon the Council, but at the care and energy such important and busy men found time to devote to the
1900.—i.

service of the Institute. No pains were spared in arriving at right conclusions respecting matters submitted to the Council. He was sure that the thanks of the meeting were due not so much to the President as to the Council and the officers for the admirable way in which the whole of the business of the Institute was carried out. He thanked them very much indeed on behalf of the Council for their vote of thanks.

The President then said—It is now my great privilege, the highest privilege that falls to a President, to make the award of the Bessemer Gold Medal, and it is with the most lively satisfaction that, in my capacity as President, I offer to you, Mr. Henri de Wendel, this medal for your acceptance. I need not remind you that it is the highest recognition which it is in our power to confer. Our Institute is up to a certain point an international one, and we have been looking forward with great pleasure to the visit to Paris this autumn, in order to meet our French friends, and to see that superb monument of the genius of France which is presented by the Exhibition. As regards your own services to our great industry, I would remind the meeting that there is a French as well as a German Lorraine, and that Mr. de Wendel has established works on both sides of the frontier—works of the greatest possible interest, because they have been adapted with singular ingenuity to meet the varying demands of commerce, and are so arranged that a change from one form of manufacture to another can readily be made. Our thanks are due to you, Mr. de Wendel, who have done so much to develop and to extend the use of those marvellous deposits of phosphoric ores in both French and German Lorraine. We are very proud, sir, not only of your works, but of your scientific investigations, and especially are we proud to be able to add your name to the illustrious list of our Bessemer Medallists. I am reminded of a remark of the great chemist, Lavoisier, whose name will be very much in our minds when we visit Paris. He said that in nature nothing is *lost* and nothing is *created*, and I cannot but feel that a bond of union, such as this Bessemer Medal, which unites us firmly with many countries, enables us to realise that the something which is lost is international prejudice, and it is lost beyond possibility of return. On the

other hand, something is created, and it is a bond of union between our nations, which I trust will never be severed. With these few remarks, I have the greatest pleasure in offering you the Bessemer Medal.

Mr. HENRI DE WENDEL, in reply, said that he was very sensible of the kind way in which his merits had been referred to. He thought that they had been very much over-rated, and that in thus deciding to add his name to the list of eminent men who had preceded him in receiving that very high honour, the Council had looked at his qualifications with very lenient eyes, and taken into consideration the long run of life which he had devoted to the iron and steel industry. He was fully conscious of the fact that the distinction conferred that day was not due to his individual effort, but to the assistance of his collaborateurs, friends, and colleagues of the Iron and Steel Institute. Amongst them he wished to mention the name of Sir Lowthian Bell, who received him thirty-five years ago, when he came to England for the first time. In conclusion, he expressed his gratitude for the very great distinction that had been conferred upon him.

On proceeding to the reading of the papers, the President said that Mr. Stead's paper was first on the list, and he would ask him to make a brief explanation as to why they would not have the pleasure of hearing him read it.

Mr. J. E. STEAD, Member of Council, said it would perhaps be a relief to know that a purely scientific paper was not to be read. He was of opinion that most members thought that purely scientific papers should never be read, but only be taken as read, and discussed at the next meeting or by correspondence. Anyhow, his paper was not to be read, for the simple reason that a week or a fortnight before the meeting he found that he had got so much additional important information that he thought it was better to withdraw the paper, and to supplement what he had written by the new matter now obtained. There were one or two things, however, which he would like to draw attention to of great practical interest, and the first was that by the

microscope they could now very easily distinguish the phosphorus compound in pig iron. He had found that iron would absorb about $1\frac{1}{2}$ per cent. of phosphorus which existed as Fe_3P in the solidified solution. The next point of interest was that if carbon was added to that saturated compound, the carbon threw the phosphide out of the solution of iron. The method of distinguishing those phosphides was not by any etching method such as had been described repeatedly at these meetings, but by the very simple process of heating the polished section upon an iron plate. They all knew how a blacksmith tempered a steel chisel. He quenched the point and rubbed it with a piece of sandstone, and waited till it passed to the proper colour of straw or blue, whichever he required, and then again quenched it. The different constituents of iron and steel were coloured quite differently when heated. The phosphides and carbides of iron coloured differently under identical treatment. When they took a piece of pig iron containing phosphorus, polished it so that it looked mirror-like in appearance, placed it upon a hot iron plate, waited till it assumed a yellowish-brown tint, then put it on one side to allow it to cool, and next placed it under a microscope, they would find a most marvellous picture. The phosphide would be found of one tint, brilliant in colour, the carbide of another and quite different colour, and the iron of another colour. The constituents were laid side by side, apparently most beautifully painted by Nature. He had under his microscope in the Council-room a specimen containing about 1 per cent. of phosphorus, which Mr. T. W. Sorby had cemented for him. Previous to cementation the microscope could not detect any phosphorus at all—all the phosphide of iron was in solidified solution; but when the carbon went in, the phosphide of iron went out and formed little pools or centres, which were clearly distinguishable under the microscope. A view of the specimen referred to would convince them that the metallurgy of iron was really assuming a very different position from what it used to do. It was the peculiar property of carbon in precipitating the phosphorus out of the solution in iron to cause the metal grains to be enveloped, and that would clearly explain how it was that phosphorus was very much more injurious in highly carbonised steels than in steels of low carbonisation.

THE USE OF FLUID METAL IN THE
OPEN-HEARTH FURNACE.

BY JAMES RILEY, VICE-PRESIDENT.

PERUSAL of the early volumes of the *Journal* of this Institute will lead one to the conclusion that the makers of steel were very much interested, not to say excited, about the results to be obtained by using fluid metal taken direct from the blast-furnace to the Bessemer converter in place of the practice then general of melting the pig iron in cupolas or reverberatory furnaces situated near the converters. The outcome of consideration and discussion was, as we know, the almost universal adoption of the "direct" process, abolishing the intermediate process of melting in the cupola. With these facts before us, it is somewhat remarkable that so very little interest has been manifested in the parallel case of the use of fluid metal taken directly from the blast-furnace to the open-hearth furnace. One would have thought that the experience obtained in the Bessemer process would have led to similar practice obtaining in the case of the competitive process. Perhaps one reason for this apparent apathy is the fact that by far the larger proportion of the Siemens steel-makers did not possess blast-furnaces, and therefore had no choice but to deal with the raw materials in the solid state. This was not universally the case, however, and one wonders why those who had the means did not prove the advantage or otherwise of the alternative practice by charging fluid metal in place of solid. It is true that statements have occasionally been current that some of our prominent managers had made trials of this process, but, for some reason or other not clearly defined, had not continued the practice, not finding it "successful."

This vague statement has come before the author on several occasions, and proved an impediment in the way of his adoption of the newer process. It may be mentioned, as indicating the foresight of the late Sir William Siemens, that the works at Llandore were planned with the object in view that the blast-furnaces should be as near as possible to the steel furnaces, so that the

metal, whether in the solid or fluid state, should be readily conveyed from one to the other; and further, that the use of the fluid metal was contemplated, for in working out the details of the pig-beds, slag-falls, boxes, and runners, the author made provision for a ladle to run under the slag-fall to receive the fluid metal for conveyance to the open-hearth furnaces. This was in the year 1872, but up to the time when the author left Landore in 1878 these arrangements were not used. Later some trials were made, and have been referred to by Mr. Carulla; but they appear to have been of a tentative character, and apparently, from one cause or another, did not make such impression as to lead to a general adoption of the process. It may be—I know not if it is—something more than a coincidence that the newer method of working was, after all, first adopted as a regular practice at these same works. My friend Colonel Wright (of Messrs. Wright and Butler) tells me that he has worked on these lines, making weekly 500 to 700 tons of steel, using fluid metal taken direct from the blast-furnace to the open-hearth furnace.

The author did not for years again have the opportunity of trying this method of working. Until five years ago, he had no blast-furnaces under his charge, and even then a considerable time elapsed before it was possible to make arrangements for its adoption. Various obstacles had to be overcome; the want of confidence in success, and the passive resistance often met with in such cases, was perhaps more discouraging than any possible difficulties which might arise in actual working, or in working out practical methods. At the Wishaw Steel Works there were, up to two years ago, some Bessemer converters with provision made for the supply to them of fluid metal direct from the blast-furnaces. In building at these works the original open-hearth furnace ordinary practice was contemplated, hence no provision was made for charging fluid metal; but in extending the works and building a new open-hearth furnace the author obtained reluctant permission to keep these arrangements in view. This was done only to the extent that the railways were laid down so that the ladles which had been used to convey the fluid metal to the converters might be brought to the doors of the furnace, and by means of improvised tackle and manual labour be tipped up into shute or runner to let their contents run into the furnace.

24 THE USE OF FLUID METAL IN THE OPEN-HEARTH FURNACE.

About this time I had paid a visit to Landore to see another process Colonel Wright was trying, and he then told me that he had already made several charges of steel in which he had used fluid metal run down a sand runner direct from the blast-furnace into the open-hearth furnace, and that they were perfectly satisfactory. We had no such facilities at Wishaw, but I was encouraged to make a trial. The blast-furnaces are situated at a considerable distance from the open-hearth furnaces. The ladles used in the Bessemer process would hold each a charge of between six and seven tons, which they received from the blast-furnace in a sunk railway. Having diverted railway connections to enable us to get the ladles to the furnaces instead of the converters, Mr. Mills, at that time the manager of the steel works, took the matter up energetically, and on 25th March 1898 made the first charge in a 25-ton furnace. The time-table of proceedings kept by Mr. Mills records:—

Blast-furnace tapped	6.25 A.M.
Both ladles full	6.35 „
Ladles weighed at melting shop	6.48 „
Shoot fixed and ladle in position	6.55 „
Finished teeming first ladle	7.0 „
Second ladle in position	7.2 „
Finished teeming second ladle	7.6 „
Shute withdrawn and door down	7.8 „
The furnace was tapped	9.30 P.M.

Evidently, although this was a pig and ore charge, the time occupied in working the charge was longer than ordinary, and this was explained by the fact that the furnace was not in thoroughly good working order, having been at work a considerable time, and was a little later put off for repairs.

But in other respects the results were encouraging. Especially was this the case in the important matter of yield.

This will be seen from the following figures:—

Charge No. 5472.	Weight charged.	
Fluid iron	12 8 0 0	
Cold pig iron	6 0 0	
	12 14 0 0	
Ferro-manganese	1 3 0	
Total metallic charge	12 15 3 0	
Ingots produced	13 5 0 0	= { 103.6 per cent. in metallic charge.
Ore charged	3 16 0 0	
Slag produced	3 5 0	with 19.4 per cent. Fe.

In reporting to me, Mr. Mills said: "The whole of the operation was, as far as conveying and weighing the hot metal from the blast-furnace to the melting-furnace, successfully performed, although owing to the care exercised it lasted considerably longer than it would in actual practice; unfortunately, however, the melting-furnace was not in a proper condition to try an experiment of any description, in proof of which is the fact that the furnace was a few days later put off for complete overhaul.

"The impression I gathered from the experiment so far as it went was that the hot metal should first be passed through a mixer, and should be conveyed to the melting-furnace with as little delay as possible, and thereafter a small amount of ore should be charged as soon as the hot metal is passed into the melting-furnace.

"The melting-furnace should be a very quick working one. The large yield of ingots in the metallic charge, viz. 103.6 per cent., should not without further figures be accepted as characteristic of the process, inasmuch as metal adhering to the bath from former charges may easily have been lifted and tapped with the one under report.

"The whole of the weights, both ingoing and outgoing, were taken on the same weigh-bridge, and ingots were check weighed in another machine."

I pass from this report, merely remarking that my interest was naturally excited about the particularly good yield, and that this result, added to the absence of difficulty in the operation, was encouraging.

And yet, as has been indicated, our appliances improvised for the occasion, and all that we could command without considerable expenditure not then permissible, caused much anxiety as to possible accident or failure through their inefficiency.

To this cause must be principally attributed the fact that several weeks passed before a further trial was made. In the course of the week ending 14th May 1898 fourteen charges in all were worked in one furnace, eleven of them being entirely fluid metal charges, one fluid metal and plate shearings, and two cold pig and scrap, the latter being due to a slight mishap at the blast-furnaces. The various points of interest which emerge on this week's work may perhaps be best stated in some of Mr.

Mill's conclusions as reported to me, and in the conclusion laid before my directors.

Mr. Mills said: "During the whole week the bogies and ladles as well as the tipping gear worked without any hitch, little or no metal was spilt, the tapping was quite clean, and without scrap. The weights of produce given include one or two small ingot ends made. The carbons were purposely kept normal and regular, the furnace bottom was good and little cut after every tap, and the series altogether was quite free from 'outside influences.'

"It was found that the hot metal ladles skulled very rapidly; the reason and remedies are discussed later on.

"The whole of the weights charged and tapped in connection with the hot metal series were observed on the same weigh-bridge, which was adjusted by Pooley on the previous Saturday, and every bogie, hot metal, and produce was tared on the same machine, before and after each weighing.

"The furnace was in excellent working order, in proof of which statement I note that during the succeeding week, May 21st, the furnace tapped 252 tons 17 cwt. of ingots, the best output since she was built.

"There were nine charges made as follows:—

"A supply of hot metal was tapped into two or four ladles at the blast-furnaces, and as quickly as circumstances would permit this was transferred into the Siemens furnace, and a small quantity of ore, 2 to 4 cwts., was thrown into the bath immediately afterwards. As soon as the metal appeared hot enough more ore was charged, and the charges worked and finished in the usual way.

"I find the 9 charges occupied 71 hours and 40 minutes, and yielded 130 tons 1 cwt. of ingots, so that assuming the whole of the 138 hours in the normal working week to be occupied to the same extent as the trials, the output would be 250 tons.

"The 'metallic' weight charged for the 9 charges was 131 tons 1 cwt., and the weight of ingots being 130 tons 1 cwt., the yield of ingots on the 'metallic' weight charged is therefore 99·23 per cent.

"The ore used for the 9 charges was 40 tons 3 cwt., or at the average rate of 6·17 cwt. per ton of steel made.

General Remarks.—I have not considered that this report should cover a definite statement of opinion on the conclusion that may be drawn from it as to the commercial value of the process, but it is evident that if satisfactory figures on which definite conclusions may be based are to be obtained, that considerable modifications in our present appliances and methods must be effected.

“For the success of the process I am fully convinced that an efficient mixer is necessary, its chief advantages being :—

“(1) It will prevent the Siemens furnaces waiting for the charges.

“(2) It will prevent hot metal waiting if the Siemens furnace bottoms require extra fettling.

“(3) It will to some extent desiliconise the hot metal.

“(4) It will enable irregularities in the different casts of hot metal to become thoroughly mixed.

“(5) It will tend to avoid the skulling of the hot metal ladles.”

In reporting to the directors the author said :—

“The object of the trials was to obtain experience on the following points :—

“(1) The facility with which the operations of conveying metal to the melting shop and charging it into melting furnaces can be performed.

“(2) The effect on furnace hearth of charging fluid metal upon it.

“(3) The possible economics of the system—

(a) At blast-furnaces.

(b) On wages at melting shop.

(c) In working these charges in melting furnaces in so far as relates to ‘output’ and to ‘yield.’

“The trials have shown that with proper arrangements

“(1) There are no difficulties or disadvantages attendant on the conveying or charging of fluid metal, except the skulling in the ladle, which, however, would in constant work be reduced to a minimum, and the metal ‘skull’ be worked up in the furnace.

“(2) That the apprehended ‘cutting’ of furnace bottom or hearth did not occur.

"(3) (a) That there were no troubles at blast-furnaces, where there would be a large saving in sand and labour on the pig-beds.

(b) That with proper arrangements the charging of the furnace can be done quite easily, and a considerable portion of the staff of men can be dispensed with, thus reducing costs and facilitating control of men.

(c) It was not anticipated that there would be any shortening of process, except in so far as quickness of charging and reduction of repairs after each charge might have this effect. The event was in accordance with this view. Mr. Mills' report shows that the following week, the best recorded, the output was 253 tons, while the charges with fluid metal were worked at the rate of 250 tons per week, and an examination of the 'time-table' shows that the 11 charges took an average of 57 minutes from tapping of blast-furnace to finish of charging into melting-furnace. With proper appliances this operation should not exceed 12 to 15 minutes as a maximum, so that $7\frac{1}{2}$ hours were lost at this stage, and a few delays occurred between tapping and charging, which taken together, I assume, represent the time necessary for an additional charge of say 25 tons, in which case the output would have been 10 per cent. over the 'record.'

"The 'yield' was surprisingly good, more than realising expectations. This is in part due to the reduced waste through the absence of sand on the metal, and in part to the increased consumption of ore. It appears that the slags were about normal in proportion to steel and also in contents of iron.

"The increased consumption of ore is an important matter, as from this source the metal is obtained at a low cost. Assuming ore at 18s. per ton with a content of 50 per cent. of iron, it is evident that the iron from it cost 36s. per ton; while in the case of pig iron with a yield of, say, 92 per cent. iron and costing 54s. per ton, the cost of iron is about 58s. 9d. per ton."

From figures submitted the author said it appeared that the metal cost for these charges nine was lower by tenpence per ton than the metal cost of the ordinary charges, worked at the same time in other furnaces, and went on to say :—

“I do not, however, wish to build too much on the results of these trials in this respect, but if they are confirmed by further trials their importance needs no emphasising—I mean if the ‘yield’ as well as the consumption of ore are confirmed by repeated trials.”

In these quotations there are clearly stated the points which struck us as being of most importance, and they will doubtless have impressed you. I will not now detain you to emphasise them.

After much consideration and long delay it was decided to dismantle the Bessemer plant at the Wishaw Steel Works and to construct open-hearth furnaces on the site, proceeding in the first instance with two furnaces of 30 tons capacity. In planning the new plant attention was focussed on the arrangements for dealing with fluid metal. The new furnaces had various novel points about them which, however, do not enter into consideration in this paper.

As the old roof of the Bessemer plant was to be used as the cover of the new furnaces, it was found that height was somewhat restricted, and as a consequence, and also to avoid costly arrangements for tipping the ladles at the steel furnaces, we ventured on a tentative plan which, if practicable, would be simple in working, and if not, could be readily altered. The ladles for conveying the metal were made fixed in their carriages, that is, not to tip. A short spout was fixed at the bottom of the ladle just under a taphole in its side. When the ladle was brought up in front of the furnace the short spout extended over a projecting sill plate, and on tapping the ladle the metal at once ran out over the latter, which is lined with brick, and so into the furnace. It may be stated now that after some experience had been gained, and the necessary facility and expertness in manipulation at the blast-furnaces and in transit to the steel furnaces, there was extremely little trouble in tapping the ladles or with the formation of skulls. But this expertness is essential; for instance, if the metal be dribbled from the blast-furnace into

the ladle at the rate of a ton per minute, it is probable the metal will be chilled, and a skull formed, and there may be a little difficulty with tapping the ladle, whereas if the metal be run at three times this speed, the regular practice, there probably will be none of these troubles. The ladles of metal are hauled along the sunk railway in front of the blast-furnaces and up an incline to the standing of the melting furnaces by wire rope. At first one carriage and ladle holding 15 tons were used, subsequently two were employed. It will have been observed that Mr. Mills made a great point of having a "mixer," and in laying out our plans provision was made for one.

I decided not to incur the considerable expenditure involved in its construction and working, although aware that some advantages might be gained by its use, the principal of which was that all the metal run at each cast of the blast-furnace might be reserved for use in the fluid state, whereas in the method adopted some of the metal, being in excess of that required for the ladle or melting-furnace, might have to be cast on the pig-bed. The other consideration, frequently reckoned an important one, that the "mixer" was necessary to obtain uniformity of quality, was very largely discounted by the regular working of the blast-furnaces as a result of very careful and watchful management on the part of those responsible in this matter. It may be mentioned that in the course of twelve months such excellent work was done in this direction that practically no iron was made which was unsuitable for charging into the open-hearth furnace, the silicon rarely reaching 3 per cent., the sulphur 0.06 per cent., and the phosphorus 0.06 per cent.

One of the furnaces was pushed on with all convenient speed, and was got to work in March last year. It was apparent that our expectations would be fully realised in all directions.

Mr. Mills shortly afterwards left Wishaw, but the work was taken up with zeal and energy by Mr. Cross.

Various matters arose in connection with the furnaces and other arrangements, which interfered with continuous working of the new process for a few months, but eventually these were overcome, and the use of the fluid metal gradually fell into a matter of daily routine.

My last information is that sixteen thousand tons of steel

have been made from charges of fluid metal, the largest week's work from one furnace having been 340 tons, and from both furnaces 670 tons.

These, be it remembered, are pig and ore charges without any scrap, which, as all steelmakers know, require a much longer time to work than charges containing a portion of scrap.

The experience over this considerable time proves :—

1. That neither at the blast-furnace nor the steel-furnace is there any difficulty in dealing with the fluid metal.

2. That at the steel-furnace the charging difficulty, which is well known to be a serious and costly one, is easily surmounted.

3. That consequently a considerable reduction can be made in the staff of men at the steel-furnace, and they are rid of the arduous labour of charging.

4. That, as compared with the working of cold charges, the output of the furnace is increased by about 30 per cent.

5. That the yield of ingots is considerably increased, rarely being less than 99 per cent. to 100 per cent. of the metallic charge.

6. That this increased yield being to a large extent due to the larger consumption of ore, the yield is obtained from a cheaper source than that of the other metal.

7. That the repairs of the furnace are little if any greater than cold charges, the consumption of sand for fettling being about the same in both cases.

8. That considerable reductions in cost result at—

(a.) The blast-furnaces, because it is not necessary to mould for pigs, nor to lift and load the pigs, and from many small incidental economies.

(b.) At the steel-furnaces, because of the reduction in staff of men; the largely increased output and yield; the reduction in the amount of gas-fuel consumed, which, although not determined, must coincide with the hour-tons of the output of furnace; and also because of the reduction of oncost charges, which, as we all know, follows increased output from a given plant.

9. That repairs at the furnace are not increased, and there is no serious trouble with the furnace hearth, as had been feared.

This important series of advantages, derived from the adoption

of the direct fluid metal process, is incontrovertible, and has convinced me that eventually this will be the process which will prevail. Just as the blast-furnace and the Bessemer converter are parts of a whole, and cannot be separated except with serious disadvantage in the working of the Bessemer process, so also the best future open-hearth practice will include the use of fluid metal direct from the blast-furnaces. In all probability it will also include one or other of the "duplex" processes; that is to say, the preliminary desiliconising in some form of the pneumatic process, followed by finishing in an open-hearth furnace, with acid or basic lining, according to the necessities of the case; or, on the other hand, desiliconising and preliminary treating, in some form of furnace, with subsequent finishing treatment as in the former case, having in conjunction with either of these plants one or more open-hearth furnaces using a very large proportion of scrap in their charges, in accordance with present practice, so that no inconvenience will be experienced in dealing with the scrap produce of the works.

The result of these innovations will undoubtedly be large economies in cost of production, without any harmful results on the quality of the product, and I am glad to have the privilege of, to some extent, contributing to their advancement.

The PRESIDENT said that, as he had already observed, before taking the discussion on Mr. Riley's paper they would listen to the paper by Mr. Talbot. Mr. Talbot was present, but he very much regretted to say that he was somewhat weak from an attack of malarial fever, and therefore wished to reserve himself for the discussion. He would therefore ask the Secretary to read the paper, but as it was some twenty-five pages in length, Mr. Talbot would agree, he was sure, to its being somewhat abridged.

Mr. Benjamin Talbot's paper on the continuous working of the open-hearth furnace was then read.

THE OPEN-HEARTH CONTINUOUS STEEL PROCESS.

BY BENJAMIN TALBOT, PENCYD, PENNSYLVANIA.

IN September of last year the author was enabled to put into practical work at the Pencoyd Steelworks, Pencoyd, Pennsylvania, a process for the continuous production of open-hearth steel, the results of which have been so satisfactory, both from a practical and theoretical standpoint, that they cannot, in the author's opinion, fail to interest manufacturers generally.

To-day two processes for the manufacture of steel stand pre-eminently before the world—the Bessemer and the open-hearth process. Both present certain advantages, and also certain disadvantages. The rapidity of the Bessemer is obtained only by a very large initial outlay, and by heavy waste of metal. The open-hearth, on the other hand, whilst giving a far higher yield per unit of metal employed, demands a much longer time, and, consequently, heavy labour charges. As usually carried out the general practice in open-hearth working is to charge solid pig iron and scrap into the furnace, and although attempts have been made to charge the furnace with molten metal it has been found that no great advantage attends this method of working, since no refining is accomplished whilst melting down, as is the case when solid material is charged into the furnace. The rapid destruction of the furnace bottom has also been found in practice to militate against charging molten metal directly on to the hearth. Again, when solid material is charged into the open-hearth, hours of valuable time are consumed before the furnace contains the necessary heat to enable the ordinary slag additions to be made in order to purify the charge, and convert the metal into steel of the desired quality.

In ordinary practice, when the bath of steel is finished the furnace is tapped and completely emptied, cooled off and repaired, and has to be heated up again before a fresh charge can be introduced to undergo the same cycle.

It is this point of intermittent refining, and the necessity of 1900.—i.

emptying the furnace and operating over a wide range of temperature, that appears to be the one upon which great improvements are possible in the output of the metal obtained in open-hearth practice.

Thus in the Bessemer, what is gained in time and labour is lost in yield; and the gain in yield in open-hearth practice is largely annulled by loss in time and cost of labour. Like all steel manufacturers, the author has given much time and attention to these questions, to see if it were not possible to manufacture steel by some process which, while giving the continuous production of the Bessemer, should also give the yield of the open-hearth. The process now at work at Pencoyd represents the results of his labours. To approach in any way the rapidity of Bessemer practice on the one hand, and the yield of the open-hearth on the other, the following conditions seem to be essential to success:—

(1) The use of fluid metal from blast-furnace, mixer, or cupola, to avoid loss of time and oxidation by air during melting in the Siemens furnace, and to utilise the heat of the molten metal.

(2) The oxidation of the metalloids should be effected entirely by means of solid oxides of iron, and not by the action of the air.

(3) Maintaining by some suitable means a large reserve of heat to keep the oxidising slags and metal in a fluid condition, and to insure the rapid removal of the metalloids from the molten pig iron.

In carrying out experiments on the refining of metal to remove the silicon and part of the phosphorus from very silicious iron, the author was particularly struck by the large amount of heat developed by the oxidation of the silicon, and the comparative immunity of the hearth from wear and tear, provided that the slag was never allowed to come in contact with the hearth, the latter being protected by a bath of metal, in other words, provided the bath was never emptied of metal. So impressed was he with these results that he determined to try if he could not carry the process further, and so modify it as to produce finished steel continuously, as if this could be shown to be feasible he saw that he would be able to carry into practice the three conditions necessary for economic production which have just been enumerated. In discussing this idea with many practical open-

hearth operators and managers, the universal opinion was that the hearth would be speedily wrecked. However, whilst these opinions were discouraging, it was thought that they were based upon conditions which would not be encountered in the author's continuous method, as the following considerations will make clear.

The great trouble with hearth and bottoms of furnaces which at times arises in ordinary practice, both acid and basic, is brought about primarily by the action of the slag, and not by the metal. If after considerable work the face of a basic hearth is examined, it will be found to be nearly of the same composition as the slag produced in the furnace. In course of time the impurities in the hearth so increase that it becomes less refractory, and cannot withstand the heat of the finished steel when hot enough to cast, and consequently holes are formed, and especially is this the case if molten metal be poured directly upon this softened hearth. To overcome this drawback the slag must be prevented from washing and impregnating the lower portion of the hearth every time the furnace is tapped. This can only be accomplished by flowing the slag off from the surface of the bath through a slag-spout at the foreplate level. Such a method of working naturally suggests a tilting-furnace, from which any percentage of metal or slag can be poured out when desired. The furnace should also tilt in both directions, so that slag can be poured off from the opposite side to the metal.

Influenced by these considerations, the writer devised the present method of working at Pencoyd, which is carried out as follows: The furnace in use is a basic-lined tilting-furnace of 75 tons capacity. The pig iron to be converted has an approximate composition of—

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
3.76	1.00	0.06	0.90	0.40

Owing to the absence of blast-furnaces, this pig iron has to be melted in cupolas. The furnace should be charged on Sunday evening with about 50 per cent. molten cupola metal and 50 per cent. of scrap, and this first (or filling) heat is worked down to steel in the usual way. When the bath is good finished steel, about one-third of it is poured off into a ladle and cast into ingots. No slag is run off with the steel. After tapping off this one-

third of the charge, oxide of iron in a fairly fine state of division is added to the slag, and as soon as this is melted about 20 tons of molten cupola metal are run in to replace the steel tapped out. An immediate very active reaction takes place, during the continuance of which the gas is cut off from the furnace. The reaction has all the characteristics of the Bessemer blow during the elimination of carbon, a large volume of CO being given off, which immediately ignites and burns with an intense flame, the heat thus produced partly raising the temperature of the bath and partly being absorbed by the regenerators. After the metal has boiled vigorously for some ten or fifteen minutes, the slag, which is now almost deprived of iron oxide, is partly poured off, and the bath worked down into finished steel by the help of fresh additions of iron ore and lime. When the bath is ready one-third (or about 20 tons) of steel is cast, fresh slag additions are made, and another 20 tons of molten cupola metal run in as before. These operations are continued during the whole of the week, the furnace being completely emptied only on the Saturday. The taphole is some few inches below the fore-plate level, so that no slag is taken in the steel ladle. This is arranged by stopping the hole sufficiently to prevent metal or slag working into it. When the furnace is ready to tap, it is tilted slightly, so that metal is above the tapping-hole, a bar is plunged through, and the metal always runs first. As soon as the desired quantity is obtained, it is tilted back over towards the charging side. This causes the level of the bath to fall well beneath the inside of the taphole, which makes it possible for the furnace-helper to *dry* and clean it rapidly, and plug it up without delay.

Whilst this is being done, the slag line is examined, gas is turned on, and whatever repairs are necessary are made by throwing raw dolomite, or limestone, mixed with 5 per cent. pitch or rosin, on the banks at a space from six to nine inches above the level of the reduced bath. The surface of the bath is very useful, as it prevents the repairing material, in a great measure, from rolling down. It acts as a floor or foundation, and tends to hold the dolomite in place. Whatever does roll down becomes incorporated in the slag, and is beneficial.

In any empty furnace much basic material rolls down into

the bottom, where it is not required, and in many cases tends to fill up the hearth.

About three hours forty minutes is the period of time between two successive casts of steel at Pencoyd, and about 27 or 28 casts are usually made per week, including the filling and emptying heats. This number of charges, however, is obtained when starting with fluid metal on Monday night, as, having only one cupola which has to be repaired each week-end, it cannot be got ready before Monday evening. Starting on Sunday night, either with cupola or blast-furnace metal, and working at the same rate as during the other part of the week, from 32 to 34 charges would readily be obtained, increasing the output at least another 100 tons per week. It is not possible to give the actual consumption of fuel, as the furnace is worked from the main gas tube, which supplies several other furnaces. It is interesting to note that from 25 to 33 per cent. less deoxidisers are required for the steel from this continuous furnace than for the other furnaces to give the same percentage of manganese (from 0.40 to 0.50 per cent.) in the finished steel.

Many hundreds of heats and thousands of tons of steel have been made by this method with very satisfactory results, all grades of metal having been produced, from dead soft up to .40 carbon steel. The question of excessive wear to the hearth, about which many doubts were entertained, and upon which the practicability of the method depended, has never given the slightest trouble, the hearth being practically in as good a condition as when put in eight months ago. This proves that a heavy surface reaction of short duration is confined to the bath, and does not affect the bottom of the hearth. As might be expected, the smaller the percentage of liquid cast iron added, the quicker this addition is purified. The data obtained proves this conclusively, as the higher the temperature the quicker the purification. It also indicates that furnaces of 100 to 120 tons capacity are quite practicable, and would be easily handled. In fact, with high-power gas, which does not require regeneration, this size will probably be surpassed.

It will thus be seen that the three conditions which the author considered necessary have been fulfilled. Liquid metal has been used without destroying the hearth, oxidation effected

entirely by oxides of iron with concentration of the heat due to chemical action in the bath of metal, and also the heat developed by the combustion of the carbonic oxide evolved; and these conditions, and the storage of a large reserve of heat to sufficiently assure the fluidity of both metal and slag, and promote rapid chemical action, are obtained by the simple expedient of maintaining a large bath of molten metal in the furnace ever ready to receive fresh additions of molten furnace metal and oxidising reagents. The retaining of this bath or pool of metal in the furnace is the vital and central feature of the process, and is the one upon which its success chiefly depends. It enables any grade of metal to be successfully used, the percentage of such metal added at any one time being varied according to its composition, and it also enables any quantity of steel to be drawn off to suit the requirements of the mills at the particular time. The high temperature of this large bath rapidly raises the temperature of smaller liquid additions, melts the oxidising and basic materials added, and thus facilitates rapid chemical action, by which more heat is produced. It may be regarded as bearing the same relation to the process as the fly-wheel does to an engine, or the accumulators to the hydraulic press, acting as a storehouse of energy, ever ready to give it out when required. In the ordinary open-hearth furnace, during the melting period, one-third of the carbon and practically the whole of the silicon and manganese are oxidised by the air during melting, and thus they are not available as reducing agents in the bath, whereas in the process under consideration the whole of these are available to reduce their equivalents of iron, and also the heat produced from their oxidation is practically concentrated in a very short space of time, with an increase in temperature of the bath similar to that produced by their combustion in the Bessemer converter. When it is remembered that, taking a metal with 3·5 carbon, 2·0 silicon, and 1·00 phosphorus, every 20 tons contains 14 cwts. of carbon, 8 cwts. of silicon, and 4 cwts. of phosphorus, it will be seen that both the reducing and heat-giving power of these constituents is not a mere piece of theory, but a practical fact.

That this is so is clearly seen by the results obtained in actual practice. In reference to the tables at the end of the paper, it will be found that the average yield extending over six

weeks' *consecutive* working has been more than 105, and that the percentage of added oxides, containing from 50 to 75 per cent. metallic iron, reduced has been 25 per cent. by weight of the metal, whereas in ordinary open-hearth practice about 10 per cent. to 15 per cent. is the maximum which can be used.

As regards the practical management of the furnace, and the question of repairs generally, a few words may now be added.

During recent years the tendency in open-hearth practice has been constantly to increase the size and capacity of the furnaces, with the result that larger ladles, cranes, &c., have to be employed to deal with the increased weight of the cast. Owing also to the length of time between each cast, the mills are not kept regularly supplied with ingots, being often unduly pressed immediately after tapping, and having to wait before the next cast can be tapped. One of the advantages of the process as carried out at Pencoyd is the regularity with which the mills can be supplied with ingots, and the weight of the metal cast regulated in accordance with the requirements of the rolling department.

With reference to the important question of scrap in connection with this method of working, solid scrap has been charged into the steel bath many times to observe whether any saving of time could be effected by diluting the carbon and phosphorus; but its chilling effect was so pronounced, that the heats could not be made as rapidly as when the impurities were eliminated by the usual oxide of iron additions. In fact, if it were possible to introduce the basic additions in a liquid condition rather than solid, the temperature of the bath would be appreciably benefited. It is probable that the present practice of charging furnaces with cold scrap, and melting this down in an oxidising flame, which results in a large waste of iron, is wrong. The question has been put, what is proposed to do with scrap when using the continuous method? The answer is, *if* it cannot be disposed of profitably, put all that is suitable through the blast-furnace. This is the most efficient melter we have, both as regards fuel and waste. The scrap will also be carbonised and will become cast iron. In the large bath of pure metal stored, we have a more than efficient substitute for cold scrap, as it is standardised in quality, and is in liquid condition.

If, therefore, we can melt scrap, impregnate it with carbon for less fuel, and with less waste, than is now taken in melting and oxidising it in the open-hearth furnace, it should be more economical to put it through the blast-furnace. By eliminating the carbon from this metal again, more oxide of iron can be reduced, and a better yield obtained, than if it were simply charged direct into the steel furnace in its de-carbonised condition. The period of time will also be saved to the steel department, which is now lost in charging scrap in detail, and waiting for its melting. This represents a serious loss in labour alone, as the leading men employed upon the furnace are skilled melters, earning large wages for refining metal. They may as well be kept busy at this purification, rather than wait for hours before obtaining a satisfactory refining temperature.

Possibly many steel works' managers may rather object to what may seem equivalent to writing their scrap down to pig iron price, but after all this is only a question of figures, and the actual value of the metal is not affected, whether it is melted in a blast-furnace cupola or open-hearth, except in so far as one is a cheaper melter than the other. In cases, however, where it may not be advisable or convenient to melt in a blast-furnace, one or two ordinary fixed Siemens furnaces working 75 to 80 per cent. scrap, by which means four to five heats can be obtained from each furnace in twenty-four hours, will readily deal with all the scrap produced. In all Siemens works, with exception of large plate mills, the difficulty is not so much to deal with scrap as to obtain sufficient quantity at a reasonable price, to enable 20 to 25 per cent. to be used in the open-hearth. No doubt this is especially felt at present prices.

In some cases it may be found convenient to establish a storage of liquid metal between the blast-furnaces and the steel furnaces. In this event the usual mixer used in Bessemer practice will be very suitable. If the metal stored should be very siliceous, it might be better to perform a certain amount of purification whilst being held. This vessel could then be a furnace, basic lined, so that an oxidising slag could be carried, which would have a refining influence upon the liquid metal added from time to time.

This preparatory furnace would quicken the operation in the

finishing furnace, for if the silicon were practically eliminated, and the carbon somewhat reduced, the metal would be purer and hotter, and so would expedite complete purification. It is not anticipated, however, that this will be necessary except in special cases, as one of the advantages of the process is the ease with which it lends itself to the production of steel from blast-furnace metal of irregular composition, owing to the large extent to which the impurities are reduced by *dilution* as apart from oxidation. Thus, assuming that 20 tons of molten pig iron containing 3·0 per cent. of silicon were teemed into the bath of 40 tons of molten finished steel, the silicon by mere admixture would be reduced in the resulting metal to 1 per cent., which is not an abnormal percentage for basic Siemens work, and, as this would be almost immediately oxidised, the somewhat silicious slag could be flowed off before it would have time to seriously attack the banks of the furnace, even if sufficiently acid to do so. This continuous method should certainly be worthy of the consideration of acid open-hearth steel manufacturers, even if they discarded the acid lining, and took up the basic, which lends itself so satisfactorily to the process. Acid bottoms gave way to the basic in puddling, and there is apparently no reason why history should not repeat itself in the case of steel.

In this age, when on the one hand the difficulty of obtaining hæmatite ores which will produce a pig with less than 0·05 per cent. of phosphorus is becoming greater and greater, and on the other hand engineers are more stringent than ever in insisting upon low phosphorus material, the adoption of this process with a basic lining would enable all those ores just outside hæmatite limit to be used, and the steel maker might with absolute certainty depend upon a finished steel produced with under 0·03 per cent. phosphorus; when using hæmatites, iron of present grade, say under 0·06 per cent. of phosphorus, still lower results would be possible.

The highest desideratum of any lining is to be passive, whilst the metal it holds is under treatment, and as this result can be obtained with a basic hearth, it should be used even if the pig metal is sufficiently pure not to require dephosphorising, providing the steel is made at a less cost.

The attached tables give the history of various heats analysed. They attempt to give a record of materials charged, and time consumed in purification.

Table "C" contains the weight of materials charged and yields obtained.

In obtaining 106 tons of steel for every 100 tons of metals charged we realise a very satisfactory result. This gain in yield has a beneficial effect in the cost sheet, and leaves a handsome margin after paying for the oxide of iron which is used to bring this about. It is a great contrast to the Bessemer, which wastes 13 per cent. or more of the pig metal to do the same work. This yield has been obtained with a low silicon metal, and will be increased with more impure metals, so that with this method we obtain exactly opposite results than with the Bessemer, for in the latter the more impure the metal the greater the loss.

The author considers that the method of working described in this paper offers advantages over the ordinary practice in many particulars. Amongst the chief of these may be cited:—

1. The cost and delay in charging cold material is avoided.
2. A saving in fuel in charging molten pig iron, and also through not cooling the furnace by charging cold material.
3. The demand for a large and regular supply of good scrap, so important in ordinary practice, is wholly dispensed with.
4. A *regular* supply of steel to the mills in any wished for quantity and at *frequent* intervals is insured.
5. An increase of output.
6. An increase of yield.
7. Less repairs to furnace.
8. Saving in labour charges, due to far less skilled labour being required per given quantity of steel.
9. The possibility of using very large furnaces, with consequent reduction in cost of production, without the necessity for very large cranes and ladles.

In conclusion, the writer must express his thanks to Mr. Percival Roberts, jun., President of the Pencoyd Iron Works, for his unfailing support, and for allowing a special plant to be built wherein it was possible to obtain satisfactory and commercial results from the start.

The writer is also indebted to Mr. Anson W. Allen, chemist of the Pencoyd Iron Works, for the large number of analyses which he has conducted in this research.

TABLE "A."—SHEET 1.

Heat No.	Time.	Name of Sample.	CHARGE.						ANALYSIS OF METAL.						ANALYSIS OF SLAG.			
			Weight of Metal.	Scale.	(Ore.	Cinder.	Limestone.	Reaction.	Carbon.	Sulphur.	Phosphorus.	Manganese.	Silicon.	Metallic Iron.	Silica.	Phosphoric Anhydride.	Manganese Oxide.	
131	A.M.	{ Tapping slag left in furnace from heat 131 } Charged	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	...	...	...	...	...	...	...	9.76	7.40	
132	8.30		{ Bath before first metal addition }	107,000	...	...	...	...	0.06	0.046	0.027	0.09	0.009	...	...	...	...
...	9.15		{ Slag before first metal addition }	...	...	...	...	...	...	...	2.990	...	...	...	...	...	...
...	0.15	Charged first cupola metal . Calculated mixture . Bath after reaction . Percentage of reduction . Slag after reaction . Charged	...	...	...	...	...	3.76	0.066	0.688	0.36	1.220	...	...	...	...
...	9.20		15,100	...	...	...	...	0.52	0.106	...	0.13	0.014	...	...	...	...
...	9.30		122,100	...	...	...	good	0.33	0.054	0.047	56%	91%	...	...	...	...
...	9.30	{ Bath before second metal addition } Slag before second metal . Charged	...	1,000	...	...	...	...	...	4.020	...	...	...	...	15.91	14.13	9.21
...	9.35		...	...	2,000	1,500	...	...	...	...	...	...	...	...	...	...	...
...	10.15		122,100	...	...	...	...	0.08	0.058	0.023	0.09	0.014	...	...	...	...	...
...	10.15	{ Slag before second metal addition } Charged second cupola metal . Calculated mixture . Bath after second reaction . Percentage of reduction . Slag after second reaction .	...	...	...	...	...	...	...	3.790	...	...	...	...	17.63	14.63	8.68
...	10.20		16,900	...	...	...	...	8.76	0.058	0.680	0.36	1.340	...	...	...	...	...
...	10.30		139,000	...	...	...	...	0.53	0.039	0.061	0.09	0.020	...	...	...	...	...
...	...	{ Bath after second reaction . Percentage of reduction . Slag after second reaction .	...	...	...	...	26%	...	41%	...	88%	...	...	...	...	...	...
...	10.30		...	...	...	...	...	...	...	3.810	...	...	...	...	16.70	15.25	8.73

Heat 132.

TABLE "A."—SHEET 2.

CHARGE			ANALYSIS OF METAL						ANALYSIS OF SLAG								
Heat Number.	Time.	Name of Sample.	Weight of Metal.	Scale.	Ore.	Cinder.	Limestone.	Manganese Ore.	Reaction.	Carbon.	Sulphur.	Phosphorus.	Silicon.	Metallie Iron.	Silica.	Phosphoric Anhydride.	Manganese Oxide.
253	12.00 noon	{ Tapping slag left in furnace from heat 253															
254	12.25 P. M.	Charged		3,800								2.960		17.19	10.27	6.78	8.69
12.50 "		Bath before first metal addition	65,000							0.05	0.041	0.016	0.12				
12.50 "		Slag before first metal addition										1.320		39.74	4.72	3.02	
12.55 "		Charged first cupola metal	16,000							3.55	0.033	0.748	1.25	0.59			
		Calculated mixture								0.74		0.161					
1.05 "		Bath after first reaction	81,000							45%	0.040	0.049	0.18				
		Percentage of reduction										68%					
1.05 "		Slag after first reaction			2,000		1,500					3.980		20.24	11.13	9.12	
1.15 "		Charged								0.39	0.039	0.046	0.19				
1.35 "		Bath before second metal addition	81,000									2.700		23.82	8.27	6.19	
1.35 "		Slag before second metal addition								3.50	0.049	0.656	1.30	0.32			
1.40 "		Charged second cupola metal	15,900							0.90		0.146					
		Calculated mixture								0.55	0.043	0.067	0.20				
1.50 "		Bath after second reaction	96,900							38 1/2		51%					
		Percentage of reduction										5.22		13.85	12.80	11.96	
1.50 "		Slag after second reaction			2,700		1,400										
2.00 "		Charged					1,400										
2.50 "		Charged						400									
3.00 "		Charged								0.06	0.041	0.019	0.15	25.79			
3.20 "		Bath before third metal addition	96,900														
3.20 "		Slag before third metal addition								3.50	0.049	0.656	1.30	0.32			
3.30 "		Charged third cupola metal	3,300							0.17		0.040					
		Calculated mixture								0.07	0.033	0.016	0.17				
3.45 "		Bath after third reaction	100,200							59 1/2		60%					
		Percentage of reduction															
3.45 "		Slag after third reaction												18.32			
3.50 "		Tapping slag								0.14	0.038	0.020	0.52	18.69	9.36	7.88	7.68
3.50 "		Finished heat (ladle test)															

Lbs.

Heat 254.

Weight of ingots produced 37,405
 Weight of scrap produced 1,200

Total weight of heat 38,605

Time from commencement of charging to tapping of heat, 2 hrs. 55 min.

TABLE "A."—SHEET 3.

Heat Number.	Time.	Name of Sample.	CHARGE.					ANALYSIS OF METAL.							ANALYSIS OF SLAG.			
			Weight of Metal.	Scale.	Ore.	Cinder.	Limestone.	Manganese Ore.	Reaction.	Carbon.	Sulphur.	Phosphorus.	Manganese.	Silicon.	Metallie Iron.	Silica.	Phosphoric Anhydride.	Manganese Oxide.
263	9.50 A.M.	{ Tapping slag left in furnace from heat 263	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.										
264	10.20 "	Charged	90,000	4,200														
11.00 "		Bath before first metal addition								0.06	0.044	0.019	0.08					
11.00 "		Slag before first metal addition																
11.05 "		Charged first cupola metal	15,800							3.80	0.059	0.836	0.68	0.47		33.28	6.30	4.70
11.05 "		Calculated mixture								0.62		0.142						
11.15 "		Bath after first reaction	105,800							good	0.34	0.051	0.037	0.13				
11.15 "		Percentage of reduction								45%			60%					
11.15 "		Slag after first reaction				2,500	1,700					4.770				14.98	12.58	10.94
11.25 "		Charged	105,800							0.08	0.044	0.025	0.12					
11.45 "		Bath before second metal addition										4.060				21.74	10.21	9.30
11.45 "		Slag before second metal addition								3.80	0.056	0.864	0.60	0.34				
11.50 "		Charged second cupola metal	14,800							0.54		0.128						
11.50 "		Calculated mixture																
12.00 noon		Bath after second reaction	120,600							good	0.35	0.042	0.069	0.14				
12.00 "		Percentage of reduction								35%			46%					
12.00 "		Slag after second reaction										4.820				18.42	11.58	11.05
12.05 P.M.		Charged		2,700		1,700	400											
12.40 "		Charged				1,400												
12.50 "		Bath before third metal addition	420,600							0.06	0.046	0.021	0.12			21.60		
1.20 "		Slag before third metal addition								3.80	0.056	0.864	0.60	0.34				
1.20 "		Charged third cupola metal	5,000							0.21		0.055						
2.05 "		Calculated mixture								0.06	0.042	0.028	0.16					
2.05 "		Bath after third reaction	125,600							71%		49%						
2.15 "		Percentage of reduction																
2.15 "		Slag after third reaction														18.03	15.87	11.42
2.15 "		Tapping slag										4.14						
2.15 "		Finished heat (ladle test)								0.14	0.038	0.030	0.39					
2.15 "																		8.11
2.15 "																		9.49

Lbs.

Heat 264.
Weight of ingots produced 39,100
Weight of scrap produced 1,850

Total weight of heat

Lbs.

. 40,950

Time from commencement of charging to tapping of heat, 3 hrs. 10 min.

TABLE "A."—SHEET 4.

CHARGE.			ANALYSIS OF METAL.						ANALYSIS OF SLAG.										
Heat Number.	Time.	Name of Sample.	Weight of Metal.	Scale.	Ore.	Cinder.	Limestone.	Manganese Ore.	Reaction.	Carbon.	Sulphur.	Phosphorus.	Manganese.	Silicon.	Metallic Iron.	Silica.	Phosphoric Anhydride.	Manganese Oxide.	
284	9.30 A.M.	{ Tapping slag left in furnace from heat 284. Charged. Bath before first metal addition. Slag before first metal addition. Charged first cupola metal. Calculated mixture. Bath after first reaction. Percentage of reduction. Slag after first reaction. Charged. Bath before second metal addition. Slag before second metal addition. Charged second cupola metal. Calculated mixture. Bath after second reaction. Percentage of reduction. Slag after second reaction. Charged. 1.00 P.M. Charged. Bath before third metal addition. Slag before third metal addition. Charged third cupola metal. Calculated mixture. Bath after third reaction. Percentage of reduction. Slag after third reaction. Tapping slag. Finished heat (ladle test).	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	...	...	...	...	...	...	10.49	11.68	13.26	7.00	
285	10.00 "		...	3,600	...	...	...	...	...	...	0.06	0.051	0.026	0.08	...	...	...	...
...	10.35 "		90,000	3.80	0.082	1.012	0.26	0.18	25.57	8.68	9.44	...
...	10.35 "		23,700	0.84	...	0.226
...	10.40 "		113,700	0.49	0.053	0.132	0.15
...	10.48 "		42%	...	42%
...	10.48 "		1,440	0.38	0.056	0.111	0.14
...	10.50 "		...	113,700
...	11.05 "		...	12,000	3.80	0.065	0.980	0.43	0.25	10.39	12.62	17.05	...
...	11.10 "		...	125,700	0.70	...	0.194
...	11.17 "	...	...	...	...	...	...	...	...	0.71	0.057	0.144	0.14	...	...	...	...	...
...	11.17 "	...	...	...	...	...	...	...	...	...	...	21%	...	...	...	...	...	...
...	11.17 "	...	...	...	...	...	2,500	2,250	...	...	...	6.750	...	...	10.71	12.32	15.56	...
...	11.20 "	...	...	...	...	...	1,000	...	...	...	...	...	...	...	...	...	...	...
...	1.00 P.M.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	1.10 "	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	2.00 "	...	125,700	...	...	...	...	...	...	0.07	0.025	0.035	0.17	...	...	...	...	...
...	2.00 "	...	...	...	...	...	...	...	...	3.80	0.065	0.980	0.43	0.25	13.95	...	...	...
...	2.05 "	...	3,000	...	...	...	...	...	...	0.16	...	0.668	...	...	...	...	...	...
...	2.05 "	...	...	...	...	...	...	...	...	0.11	0.033	0.041	0.18	...	...	...	...	...
...	2.10 "	...	128,700	...	...	...	...	...	...	31%	...	29%	...	...	...	...	...	...
...	2.10 "	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	2.10 "	...	...	...	...	...	...	...	...	...	...	...	...	...	11.59	...	...	...
...	2.10 "	...	...	...	...	...	...	...	...	...	...	...	...	...	11.81	11.55	12.03	7.83
...	2.10 "	...	...	...	...	...	...	...	...	0.16	0.050	0.036	0.50	...	...	...	...	...

Lbs.

Heat 285.

Weight of ingots produced

Weight of scrap produced

Total weight of heat

Time from commencement of charging to tapping of heat, 3 hrs. 25 min.

TABLE "A."—SHEET D.

Heat Number.	Time.	Name of Sample.	CHARGE.					ANALYSIS OF METAL.							ANALYSIS OF SLAG.			
			Weight of Metal.	Scale.	Ore.	Cinder.	Limestone.	Manganese Ore.	Reaction.	Carbon.	Sulphur.	Phosphorus.	Manganese.	Silicon.	Metallic Iron.	Silica.	Phosphoric Anhydride.	Manganous Oxide.
305	10.20 A.M.	{ Tapping slag left in furnace from heat 306	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.											
306	11.00 "	Charged		3,800														
	11.30 "	Bath before first metal addition	95,000															
	11.30 "	Slag before first metal addition																
	11.35 "	Charged first cupola metal	14,000															
	11.45 "	Calculated mixture																
	11.45 "	Bath after first reaction	109,000															
	11.45 "	Percentage of reduction																
	12.00 "	Slag after first reaction																
	12.00 noon	Bath before second metal addition	109,000															
	12.00 "	Slag before second metal addition																
	12.05 P.M.	Charged second cupola metal	17,200															
	12.20 "	Calculated mixture																
	12.20 "	Bath after second reaction	126,200															
	12.20 "	Percentage of reduction																
	12.25 "	Slag after second reaction																
	12.25 "	Charged																
	2.10 "	Bath before third metal addition	126,200															
	2.55 "	Slag before third metal addition																
	3.00 "	Charged third cupola metal	6,100															
	3.10 "	Calculated mixture																
	3.10 "	Bath after third reaction	132,300															
	3.10 "	Percentage of reduction																
	3.15 "	Slag after third reaction																
	3.15 "	Tapping slag																
	3.15 "	Finished heat (ladle test)																

Lbs.

Heat 306.

Weight of ingots produced . . .

37,410

Weight of scrap produced . . .

745

Total weight of heat . . .

38,155

Time from commencement of charging to tapping of heat, 3 hrs. 40 min.

Heat Number.	Time.	Name of Sample.	CHARGE.		ANALYSIS OF METAL.						ANALYSIS OF SLAG.		
			Weight of Metal.	Cinder.	Remarks.	Carbon.	Sulphur.	Phosphorus.	Manganese.	Silicon.	Metallo Iron.	Silica.	Phosphoric Anhydride.
			Lbs.	Lbs.		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
305	9.45 P.M.	Bath before third metal addition	104,000	...	Bath hot enough to tap	0.06	0.051	0.022	0.06	0.012	22.42	8.80	10.18
9.45 "		Slag before third metal addition	...	...	...	...	...	...	...	...	...	...	...
9.50 "		Charged third cupola metal	9,300	...	Finished pouring 9.54	3.80	0.065	0.440	0.36	0.470	...	...	...
...		Calculated mixture	...	...	...	0.37	0.102	0.049	0.049	...	...	...	...
9.56 "		Bath after third reaction	113,300	...	Bath hot enough to tap	0.13	0.048	0.053	0.10	0.010	...	...	...
...		Percentage of reduction	...	...	...	65	...	48	...	80	...	...	...
9.56 "		Slag after third reaction	...	...	...	...	...	5.71	...	...	12.48	11.41	13.08
10.00 "		Charged.	...	800	...	...	...	...	...	...	...	...	...
10.20 "		Finished heat (ladle test)	...	...	...	0.14	0.056	0.041	0.36	...	...	...	...

Heat 305.

TABLE "B."

Heat Number.	First Liquid Metal Addition.						Second Liquid Metal Addition.						Third Liquid Metal Addition.					
	Calculated Mixture.			Per Cent. Reduction.			Calculated Mixture.			Per Cent. Reduction.			Calculated Mixture.			Per Cent. Reduction.		
	C.	P.	C.	P.	C.	P.	C.	P.	C.	P.	C.	P.	C.	P.	C.	P.	C.	P.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
132	0.52	0.106	0.33	0.047	33	56	0.53	0.103	0.39	0.061	27	41	0.17	0.040	0.07	0.016	59	60
254	0.74	0.161	0.39	0.046	47	72	0.92	0.148	0.55	0.067	40	55	0.21	0.055	0.06	0.028	71	49
264	0.62	0.142	0.34	0.057	45	60	0.54	0.128	0.35	0.069	35	46	0.16	0.056	0.11	0.041	31	29
285	0.84	0.226	0.49	0.132	42	42	0.70	0.194	0.71	0.144	...	21	0.37	0.102	0.13	0.053	65	48
305	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
306	0.54	0.165	0.11	0.062	80	62	0.60	0.180	0.34	0.111	43	38	0.24	0.067	0.07	0.030	71	55
408	0.51	0.139	0.25	0.067	51	52	0.53	0.146	0.47	0.068	11	33	0.13	0.049	0.09	0.034	31	30

TABLE "C."—SHEET 1.

Heat Number.	TIME.					CHARGES.				
	Commenced Charging.	Finished Charging.	Heat Topped.	Hours in Furnace.		Cold Pig Iron.	Liquid Metal.	Scrap.	Iron Ore.	Manganese Ore.
				Hrs.	Min.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
243	6.00 P.M.	5.50 A.M.	8.00 A.M.	14	00	3,000	53,000	49,300	8,000	...
244	9.45 A.M.	2.30 P.M.	3.00 P.M.	5	15	400	44,500	...	8,000	...
245	4.30 P.M.	8.16 "	8.35 "	4	05	500	40,800	...	7,000	...
246	9.45 "	1.30 A.M.	1.45 A.M.	4	00	500	31,300	...	4,500	...
247	3.15 A.M.	6.30 "	7.15 "	4	00	600	33,700	...	4,500	...
248	8.35 "	12.25 P.M.	12.45 P.M.	4	10	800	37,800	...	5,000	400
249	1.45 P.M.	5.50 "	6.05 "	4	30	500	37,500	...	5,000	400
250	7.15 "	10.30 "	10.50 "	3	35	500	34,100	...	5,000	500
251	11.30 "	2.45 A.M.	3.00 A.M.	3	20	500	33,100	...	5,000	500
252	4.00 A.M.	7.10 "	7.45 "	3	45	600	38,800	...	3,800	400
253	8.50 "	11.40 "	12.00 noon.	3	10	600	34,900	...	2,000	400
254	12.55 P.M.	3.30 P.M.	3.50 P.M.	2	55	600	34,400	...	2,000	400
255	4.35 "	7.00 "	7.15 "	2	40	500	31,800	...	5,000	...
256	8.35 "	11.20 "	11.40 "	3	15	500	42,700	...	2,000	...
257	12.45 A.M.	3.40 A.M.	4.00 A.M.	3	15	500	40,500	...	2,000	...
258	5.00 "	8.30 "	8.50 "	3	50	600	37,300	...	6,000	...
259	9.55 "	1.30 P.M.	1.45 P.M.	3	50	600	34,200	...	300	400
260	2.50 P.M.	7.00 "	7.15 "	3	50	600	40,600	...	2,000	500
261	8.30 "	12.41 A.M.	1.00 A.M.	4	30	600	40,900	...	2,000	500
262	2.05 A.M.	5.20 "	5.35 "	3	30	600	35,700	...	6,000	500
263	6.30 "	9.35 "	9.50 "	3	20	600	38,300	...	...	400
264	11.50 "	2.03 P.M.	2.15 P.M.	3	10	1,000	35,600	...	2,700	400
265	3.20 P.M.	7.20 "	8.10 "	4	50	600	41,100	...	4,600	400
266	9.15 "	12.05 A.M.	12.25 A.M.	3	10	600	35,900	...	5,000	400
267	1.25 A.M.	5.00 "	5.25 "	4	00	600	38,400	...	1,000	400
268	6.24 "	9.35 "	9.50 "	3	25	600	36,700	...	5,000	400
269	11.20 "	12.45 P.M.	6.45 P.M.	7	25	800	60,000	...	9,000	500
270	6.45 P.M.	...	7.30 "	0	45	1,000	...	...	...	...
Total (28 heats in all)						19,400	1,045,900	49,300	112,400	7,600

Starting with fluid metal on
Pig iron and metal charged,
Ingots and scrap produce,
Yield, 105'4 long tons ingots

TABLE "C."—SHEET 1.

CHARGES.					PRODUCT.			ANALYSIS.			
Cinder.	Scale.	Limestone.	Ferro-manganese.	Silico-spiegel.	Ingots.	Scrap.	Per Cent. Gain.	Carbon.	Sulphur.	Phosphorus.	Manganese.
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	P. Cent.	P. Cent.	P. Cent.	P. Cent.
...	...	4,500	300	100	51,590	2,100	...	0.17	0.046	0.033	0.52
...	3,000	4,500	140	75	34,605	1,950	...	0.14	0.047	0.071	0.42
...	3,500	4,500	125	75	36,595	800	...	0.17	0.051	0.075	0.55
...	3,500	4,500	125	75	35,225	900	...	0.16	0.046	0.058	0.56
...	3,500	4,500	140	75	38,500	3,100	...	0.14	0.038	0.063	0.52
...	3,500	4,500	140	75	36,240	950	...	0.16	0.050	0.050	0.42
...	3,500	4,500	125	75	36,450	1,150	...	0.12	0.061	0.073	0.48
...	3,500	4,500	125	75	36,825	1,000	...	0.12	0.053	0.033	0.42
...	3,500	4,500	125	75	37,345	1,500	...	0.12	0.054	0.045	0.49
...	...	4,500	140	75	37,730	2,400	...	0.16	0.046	0.035	0.44
3,000	3,000	4,500	140	75	37,625	2,200	...	0.19	0.040	0.034	0.57
...	3,800	4,500	140	75	37,405	1,200	...	0.14	0.038	0.020	0.52
...	3,500	4,500	125	75	38,385	900	...	0.10	0.046	0.047	0.34
5,000	...	4,500	125	75	38,150	850	...	0.14	0.055	0.071	0.57
5,000	3,500	4,500	125	75	37,935	1,150	...	0.13	0.058	0.060	0.56
...	...	4,500	140	75	37,155	2,400	...	0.38	0.057	0.072	0.58
5,200	3,600	3,900	140	75	39,930	1,750	...	0.14	0.036	0.028	0.54
4,600	3,500	4,500	125	75	35,655	2,800	...	0.19	0.055	0.047	0.53
5,000	3,500	4,500	125	75	36,960	2,200	...	0.19	0.057	0.054	0.55
...	3,500	4,500	125	75	37,775	2,050	...	0.16	0.045	0.060	0.54
5,000	3,500	4,500	140	75	37,205	1,900	...	0.15	0.040	0.027	0.53
2,500	4,200	4,800	140	75	39,100	1,850	...	0.14	0.038	0.030	0.39
...	3,000	4,800	125	75	38,590	1,100	...	0.13	0.036	0.034	0.46
5,000	3,500	4,500	125	75	38,090	1,150	...	0.16	0.034	0.063	0.55
5,000	3,000	4,500	125	75	38,530	1,100	...	0.16	0.042	0.052	0.50
...	...	4,500	330	100	62,170	4,850	...	0.16	0.042	0.035	0.48
...	5,000	6,300	330	100	66,675	1,000	...	0.17	0.051	0.041	0.61
...	...	1,000	330	100	52,510	4,200	...	0.14	0.049	0.055	0.44
40,000	77,600	114,200	4,440	2,200	1,130,950	50,500	5.4	...	...	...	...

nday night.

*5 long tons.

*4 long tons.

.scrap for every 100 tons of metal charged.

NOWAB SALAH JUNG BAHADUR

TABLE "C."—SHEET 2.

Heat Number.	TIME.				CHARGES.				
	Commenced Charging.	Finished Charging.	Heat Tapped.	Hours in Furnace.	Cold Pig Iron.	Liquid Metal.	Scrap.	Iron Ore.	Manganese Ore
				Hrs.	Min.	Lbs.	Lbs.	Lbs.	Lbs.
399	6.00 P.M.	10.15 P.M.	9.30 A.M.	15	30	1,300	95,700	22,750	1,580
400	11.20 A.M.	4.00 "	4.15 P.M.	4	55	1,300	38,600	...	4,800
401	5.25 P.M.	10.40 "	10.50 "	5	25	1,000	40,600	...	5,500
402	11.30 "	4.15 A.M.	4.30 A.M.	5	00	2,000	38,700	...	5,810
403	5.30 A.M.	10.30 "	11.00 "	5	30	1,500	42,600	...	5,700
404	11.15 "	5.05 P.M.	5.15 P.M.	5	20	1,200	42,100	...	4,400
405	5.45 P.M.	10.25 "	10.35 "	4	50	800	40,000	...	900
406	11.05 "	3.10 A.M.	3.20 A.M.	4	15	800	40,500	...	1,700
407	3.55 A.M.	8.40 "	9.00 "	5	05	600	45,600	...	3,200
408	9.55 "	1.10 P.M.	1.30 P.M.	3	35	800	36,200	...	4,400
409	2.45 P.M.	6.25 "	6.45 "	4	00	900	35,100	...	700
410	7.20 "	11.15 "	11.25 "	4	05	900	41,300	...	2,100
411	12.00 A.M.	4.30 A.M.	4.40 "	4	00	900	40,600	...	1,500
412	5.35 "	9.05 "	10.00 A.M.	4	25	1,800	39,200	...	1,100
413	11.15 "	2.05 P.M.	2.40 P.M.	3	25	650	38,400	...	900
414	3.50 P.M.	7.55 "	8.05 "	4	15	800	37,800	...	2,750
415	8.45 "	12.35 A.M.	12.45 A.M.	4	00	2,000	41,400	...	5,600
416	1.35 A.M.	5.30 "	5.45 "	4	10	1,000	35,100	...	5,100
417	6.15 "	9.05 "	11.30 "	5	15	1,450	34,300	...	5,150
418	12.15 P.M.	3.00 P.M.	3.45 P.M.	3	30	850	37,900	...	5,150
419	4.30 "	8.25 "	8.35 "	4	05	800	39,100	...	5,100
420	9.05 "	12.30 A.M.	12.40 A.M.	3	35	1,600	35,200	...	...
421	1.10 A.M.	4.00 "	4.10 "	3	00	2,000	36,500	...	2,300
422	5.00 "	9.15 "	9.40 "	4	40	1,200	40,200	...	1,000
423	10.30 "	11.35 "	5.40 P.M.	7	10	1,300	59,400	...	...
424	5.40 P.M.	...	7.00 "	1	20	1,200	...	...	...
425	7.00 A.M.	...	7.55 "	0	55	500	...	...	...
Total (27 heats in all)						31,150	1,053,100	22,750	89,810
									23,250

Total weight of slag produced, 219,000 pounds.

Starting with fluid metal on
Pig iron and metal charged,
Ingots and scrap produced,
Yield, 106 tons of ingots and

TABLE "D."

Analysis of Slag at End of Week when Emptying the Furnace.

Week ending	Nov. 25, 1889.	Dec. 2, 1899.	Jan. 6, 1900.	Jan. 13, 1900.	Feb. 17, 1900.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Iron protoxide (calculated).	16.61	19.02	18.23	17.24	20.21
Silica	18.79	11.42	14.52	15.60	12.08
Calcium oxide	37.65	40.62	40.69	38.29	38.08
Magnesium oxide . . .	7.37	6.01	6.45	9.36	5.93
Phosphoric anhydride .	7.08	8.04	7.85	7.56	8.63
Manganous oxide . . .	8.91	11.69	9.70	9.75	12.40
Metallic iron	12.92	14.79	14.17	13.40	15.72
Metallic phosphorus . .	3.09	3.51	3.42	3.29	3.64

	Metallic Iron.	Silica.	Phosphoric Anhydride.
	Per Cent.	Per Cent.	Per Cent.
Port Henry iron ore	58.00	3.00	4.35
Scale	74.50	0.50	0.07
Cinder	66.80	8.00	0.23

TABLE "E."

Summary of Six Weeks' Working, Starting with Fluid Metal on Monday Night.

Average Number of Heats per Week.	Average Number of Hours in the Furnace.*	Average Weight of Metals Charged per Week.	Average Weight of Ingot and Scrap Produced per Week.	Average Yield of Ingot and Scrap per 100 parts of Metal Charged.
27	3.8	Long Tons. 488	Long Tons. 517	105.94

* Exclusive of filling and emptying heats.

Owing to the special conditions of working at Pencoyd, it had not been possible to arrive at an accurate estimate of the fuel consumption at the time the manuscript was first sent to the Secretary, but just before leaving the States the author was able to disconnect the producer supplying the gas to the furnace from the battery of producers connected with the other furnaces; and from a large number of heats during the last two weeks it was shown that when working heats equal to 25 per cent. of the charge, the fuel was about $4\frac{1}{2}$ to 5 cwt., and in experiments with 10 per cent. charges the fuel fell below 3 cwt. per ton. The experiments were not continued, as regards these smaller charges, for sufficient length of time to enable the author to give these latter figures as absolute, but from the experience gained, he was convinced that with 150-ton furnace working heats at 15 to 20 tons, the fuel would not greatly exceed this last amount.

In the paper the author has confined the description of his process to his work in the tilting furnace, as from experience gained with fixed furnaces he is convinced that to work the process economically a tilting furnace is necessary. He has, however, made numerous experiments in fixed furnaces by building up charges by repeated small additions, also by one or two larger additions of fluid metal to a small initial bath covered with an oxidising slag, and that the process can be worked in this manner has been clearly proved. The practical difficulties, however, are great, owing to the cutting and softening action of the slag affecting a large area of the hearth, the difficulty of removing the slag when exhausted, and the risk of the slag boiling over the foreplate and into the ports directly the furnace has received anything like its full charge. It was found, in fact, that, to avoid accidents to ports, it was practically necessary to work only about 20-ton heats in 30-ton furnaces, and although these were worked much quicker, and the method presented advantages over the ordinary system of Siemens work, the author most strongly advises the use of a tilting furnace for working his process, whether the entire heat is tapped or not. The result of the last two weeks' working gave a yield of 107·5 tons, and details are appended.

Heat Number.	TIME.				CHARGES.				
	Commenced Charging.	Finished Charging.	Heat Tapped.	Hours in Furnace.	Cold Pig Iron.	Liquid Pig Metal.	Cold Scrap.	Iron Ore.	Manganese Ore.
				Hrs. Mins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
529	10.00 P.M.	11.00 A.M.	12.00 Noon	14 00	2,000	59,600	39,700	8,600	700
530	1.15 "	7.05 P.M.	7.30 P.M.	6 15	400	47,200	...	6,950	...
531	8.10 "	2.30 A.M.	2.55 A.M.	6 45	800	57,800	...	8,100	1,000
532	3.40 A.M.	8.30 "	8.40 "	5 00	600	38,300	...	6,100	700
533	9.30 "	2.13 P.M.	2.40 P.M.	5 10	1,000	37,500	...	5,000	700
534	3.05 P.M.	7.15 "	7.45 "	4 40	...	41,100	...	3,000	700
535	8.30 "	11.15 "	11.25 "	2 05	...	28,700	...	1,000	900
536	12.10 A.M.	3.05 A.M.	3.10 A.M.	3 00	750	28,400	...	1,200	800
537	4.00 "	7.15 "	7.25 "	3 25	600	28,700	...	1,500	900
538	8.20 "	12.20 P.M.	12.35 P.M.	4 15	700	34,800	...	5,000	700
539	12.55 P.M.	4.40 "	4.50 "	3 55	400	36,800	...	4,100	1,700
540	5.50 "	8.40 "	9.15 "	3 25	...	29,100	...	2,100	1,100
541	9.45 "	1.30 A.M.	1.40 A.M.	3 55	...	37,800	...	4,000	600
542	2.40 A.M.	5.20 "	5.25 "	2 45	800	28,600	...	1,000	1,600
543	5.50 "	9.50 "	10.25 "	4 35	...	40,300	...	1,200	1,150
544	10.40 "	1.15 P.M.	2.25 P.M.	3 45	...	32,800	...	3,500	...
545	2.55 P.M.	6.25 "	6.30 "	3 35	2,000	33,400	...	2,450	1,000
546	7.05 "	9.40 "	10.10 "	3 05	1,000	27,600	...	2,700	900
547	11.05 "	1.50 A.M.	2.20 A.M.	3 15	400	28,900	...	3,000	1,000
548	3.05 A.M.	7.45 "	7.50 "	4 45	600	33,100	...	3,950	1,000
549	8.20 "	12.15 P.M.	12.40 P.M.	4 20	600	40,700	...	1,000	50
550	1.05 P.M.	3.30 "	4.00 "	2 55	...	28,400	...	1,500	...
551	4.30 "	8.10 "	8.30 "	4 05	...	30,400	...	...	1,200
552	9.00 "	12.00 "	1.35 A.M.	4 35	...	39,600	...	1,000	1,175
553	2.05 A.M.	5.20 A.M.	6.00 "	3 55	400	41,000	...	2,750	400
554	6.35 "	10.45 "	10.55 "	4 20	600	38,900	...	6,200	800
555	11.55 "	1.05 P.M.	1.55 P.M.	8 00	1,450	49,900	...	7,900	1,500
556	7.55 P.M.	...	8.50 "	0 55	1,000	...	...	...	...
Total (28 heats in all)					16,100	999,400	39,700	94,800	21,625

CHARGES.					PRODUCT.			ANALYSIS.			
Cinder.	Scale.	Limestone.	Ferro-manganese.	Silico-spiegel.	Ingots.	Scrap.	Per Cent. Gain.	Carbon.	Sulphur.	Phosphorus.	Manganese.
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.		P. Cent.	P. Cent.	P. Cent.	P. Cent.
4,500	...	8,000	125	50	37,670	2,650	...	0.14	0.056	0.047	0.42
...	3,500	4,100	125	50	37,795	2,350	...	0.15	0.065	0.049	0.50
2,200	3,700	4,100	120	50	37,300	1,350	...	0.18	0.085	0.091	0.54
...	2,600	4,200	125	50	39,615	1,050	...	0.13	0.061	0.038	0.43
...	3,600	4,000	120	50	38,200	805	...	0.14	0.056	0.049	0.42
4,500	4,000	4,000	100	40	30,820	1,300	...	0.16	0.072	0.066	0.36
2,100	3,900	2,400	100	40	35,950	1,200	...	0.15	0.061	0.066	0.46
2,100	3,700	2,600	100	40	33,675	2,720	...	0.14	0.065	0.067	0.42
2,000	3,700	4,000	125	50	37,900	800	...	0.14	0.064	0.068	0.46
...	3,600	4,800	125	50	39,325	1,400	...	0.14	0.052	0.049	0.55
...	3,800	4,400	125	50	38,905	650	...	0.14	0.051	0.056	0.62
...	3,600	2,600	100	40	31,200	2,120	...	0.16	0.050	0.112	0.50
2,000	3,600	4,000	100	40	30,900	1,650	...	0.17	0.053	0.039	0.58
1,900	3,900	2,700	100	40	38,270	1,200	...	0.13	0.046	0.052	0.40
2,000	3,600	4,200	100	50	32,860	1,000	...	0.13	0.051	0.038	0.50
...	3,700	3,600	100	50	32,150	1,100	...	0.13	0.048	0.029	0.32
...	3,600	2,200	100	40	31,460	2,020	...	0.15	0.060	0.053	0.51
...	3,750	2,200	100	40	31,335	2,050	...	0.20	0.055	0.072	0.48
...	3,870	3,200	100	40	31,830	1,750	...	0.13	0.063	0.083	0.46
...	3,700	3,600	125	50	38,585	1,900	...	0.11	0.049	0.071	0.44
2,500	3,600	3,600	100	15	31,100	2,850	...	0.16	0.046	0.052	0.40
2,150	3,600	2,150	100	50	31,520	950	...	0.13	0.050	0.051	0.44
2,700	3,500	4,000	125	50	37,755	2,100	...	0.15	0.054	0.040	0.58
4,200	3,800	4,000	150	50	49,450	2,650	...	0.12	0.066	0.042	0.40
1,900	3,300	2,400	150	50	47,225	1,000	...	0.13	0.067	0.057	0.38
...	3,400	3,900	330	100	70,810	2,400	...	0.14	0.057	0.029	0.46
2,000	3,600	6,500	330	100	68,355	850	...	0.11	0.063	0.079	0.39
...	...	...	250	50	51,420	3,450	...	0.06	0.064	0.077	0.22
38,750	96,220	99,450	3,730	1,465	1,093,480	48,315	7.7	...	...	...	...

TIME.					CHARGES.				
Heat Number.	Commenced Charging.	Finished Charging.	Heat Tapped.	Hours in Furnace.	Cold Pig Iron.	Liquid Pig Metal.	Cold Scrap.	Iron Ore.	Manganese Ore.
				Hrs. Min.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
557	6.05 P.M.	7.05 A.M.	9.00 A.M.	14 55	900	54,000	55,900	8,000	1,500
558	9.10 A.M.	4.15 P.M.	5.30 P.M.	8 20	1,500	54,500	...	9,700	1,200
559	6.30 P.M.	10.45 "	11.00 "	4 30	1,000	31,200	...	3,900	1,000
560	12.05 A.M.	3.45 A.M.	4.00 A.M.	3 55	1,000	29,100	...	3,200	800
561	5.20 "	8.45 "	9.30 "	4 10	...	31,800	...	3,700	1,000
562	10.05 "	2.10 P.M.	2.15 P.M.	4 10	...	38,900	...	1,100	400
563	2.50 P.M.	7.40 "	7.50 "	5 00	1,000	51,500	...	2,400	800
564	8.40 "	11.25 "	12.10 A.M.	3 30	700	29,600	...	3,200	800
565	12.35 A.M.	4.30 A.M.	4.35 "	4 00	700	32,000	...	2,400	1,200
566	5.10 "	9.10 "	9.15 "	4 05	...	34,700	...	4,200	400
567	9.50 "	2.25 P.M.	3.00 P.M.	5 10	400	48,000	...	4,800	...
568	3.20 P.M.	8.00 "	8.35 "	5 15	600	37,800	...	3,400	...
569	8.55 "	1.05 A.M.	1.15 A.M.	4 20	500	34,100	...	2,500	...
570	2.00 A.M.	5.30 "	5.40 "	3 40	600	34,900	...	1,000	...
571	6.20 "	10.40 "	10.55 "	4 35	...	44,700	...	1,000	...
572	11.35 "	3.55 P.M.	4.05 P.M.	4 30	...	42,700	...	3,400	...
573	4.25 P.M.	8.40 "	8.50 "	4 25	...	38,700	...	6,500	...
574	9.30 "	1.00 A.M.	1.10 A.M.	3 40	400	34,800	...	1,800	...
575	1.55 A.M.	5.35 "	5.50 "	3 55	...	36,800	...	1,500	...
576	6.40 "	10.35 "	10.45 "	4 05	200	44,200	...	...	...
577	11.20 "	3.35 P.M.	3.45 P.M.	4 25	...	42,800	...	1,500	...
578	4.15 P.M.	7.20 "	7.30 "	3 15	700	35,900	...	...	...
579	8.30 "	12.30 A.M.	1.30 A.M.	5 00	3,000	35,700	...	...	800
580	2.35 A.M.	5.15 "	5.25 "	2 50	700	25,000	...	3,000	...
581	6.15 "	7.35 "	12.45 P.M.	6 30	800	61,700	...	4,000	...
582	12.45 P.M.	...	4.00 "	3 15	1,000	...	...	...	...
583	4.00 "	...	5.30 "	1 30	800	...	...	...	...
Total (27 heats in all)					16,500	985,100	55,900	76,200	9,900

CHARGES.					PRODUCT.			ANALYSIS.			
Cinder.	Scale.	Limestone.	Ferro-manganese.	Silico-spiegel.	Ingots.	Scrap.	Per Cent. Gain.	Carbon.	Sulphur.	Phosphorus.	Manganese.
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.		P. Cent.	P. Cent.	P. Cent.	P. Cent.
2,400	...	6,800	125	50	39,235	1,600	...	0.13	0.082	0.087	0.46
...	3,500	5,100	125	50	39,050	840	...	0.12	0.066	0.069	0.47
...	4,200	4,300	100	50	31,350	2,150	...	0.15	0.056	0.042	0.47
...	4,000	3,900	100	50	28,655	1,850	...	0.14	0.046	0.047	0.52
...	3,800	2,800	125	50	36,520	1,200	...	0.14	0.062	0.056	0.51
4,500	3,800	3,900	125	50	39,110	920	...	0.14	0.053	0.049	0.44
6,900	3,400	5,100	100	50	31,560	820	...	0.14	0.047	0.058	0.42
...	3,700	3,600	125	50	38,060	1,100	...	0.16	0.056	0.056	0.46
...	3,600	3,900	125	50	38,060	1,900	...	0.17	0.045	0.051	0.48
...	3,700	2,600	125	50	36,085	2,250	...	0.17	0.053	0.078	0.41
4,500	5,300	4,800	150	50	46,050	750	...	0.20	0.062	0.062	0.50
4,200	3,800	3,850	125	50	36,180	1,100	...	0.12	0.056	0.048	0.53
4,000	3,600	3,700	125	50	37,540	740	...	0.14	0.068	0.045	0.48
4,600	3,600	3,700	125	50	39,150	940	...	0.14	0.056	0.028	0.47
4,700	7,500	3,500	150	50	42,285	2,750	...	0.15	0.066	0.033	0.48
...	7,800	4,100	150	50	45,720	960	...	0.15	0.064	0.047	0.36
...	3,500	4,100	125	50	39,195	1,100	...	0.14	0.059	0.045	0.43
1,500	3,700	5,200	125	50	39,375	2,350	...	0.14	0.065	0.059	0.44
2,400	5,500	3,600	125	50	39,420	1,250	...	0.18	0.060	0.043	0.43
4,500	7,900	2,600	150	50	45,920	940	...	0.20	0.080	0.056	0.48
2,300	7,300	2,950	150	50	44,740	650	...	0.12	0.050	0.031	0.38
4,600	3,500	4,100	125	50	38,550	1,750	...	0.16	0.059	0.035	0.49
2,000	6,200	3,800	125	50	46,485	1,500	...	0.14	0.071	0.068	0.42
...	3,600	4,000	125	50	71,065	2,050	...	0.14	0.074	0.076	0.48
7,900	4,000	6,300	330	100	74,030	1,500	...	0.15	0.090	0.093	0.49
...	...	...	330	100	42,000	4,500	...	0.10	0.066	0.100	0.38
...	...	...	75	50	26,400	4,380	...	0.10	0.067	0.076	0.53
6,100	110,500	102,300	3,785	1,450	1,111,800	33,840	7.8	...	...	...	...

DISCUSSION.

The PRESIDENT, in inviting discussion upon the paper, said he would point out that they had present a very large number of distinguished people from all parts of the world, and he would suggest that members should reduce their remarks to as small a compass as possible, in order that they might have an opportunity of hearing them all.

The PRESIDENT added that they had heard one of the most remarkable contributions they had ever had in the history of the open-hearth furnace. He would now invite gentlemen present to take part in the discussion.

Mr. G. J. SNELUS (Vice-President) said that the papers by Mr. Riley and Mr. Talbot deserved the most serious consideration of every one interested in the manufacture of iron and steel. The improvement in open-hearth practice reported by Mr. Talbot constituted the greatest advance that had been made in the manufacture of steel for some years. Through the courtesy of Mr. Harbord he had the opportunity of studying the results obtained some little time in advance of the paper, and had carefully read through the elaborate paper of Mr. Talbot itself, and studied the analytical results with every intention of finding out any fault, and also finding out the points of value. He must say that the chemical results were most interesting, and bore evidence of the greatest care and skill on the part of the analyst, Mr. Anson Allen. Mr. Talbot had used such conditions that the fullest effect could be obtained from the interaction of the metalloids contained in molten pig iron with oxide of iron, so as not only to remove the metalloids, but also to obtain the metal from the oxide of iron added, and thus get a yield of steel considerably in excess of the pig iron charged. It might be remembered that the first occasion on which a regular yield of metal in excess of the pig iron charged was recorded was on the occasion of the investigation of the Danks puddling furnace in America in

1872. The increase of yield was so remarkable that it fell to his lot to explain how it could occur, and it would be remembered that he then propounded the theory that the increase was due to the reaction between the metalloids and the oxide of iron used for the fettling. It was highly gratifying to find that the theory then advanced was now so amply verified. He had on several occasions pointed out the importance of endeavouring to bring molten pig iron into intimate contact with molten oxide of iron, so that the interaction could be brought about rapidly, and thus get the greatest amount of metal reduced from the oxide of iron by the metalloids; and with this object in view he some years ago took out an English patent for carrying out this process in a rotatory furnace, but no opportunity of putting this into practice had occurred. However, it was still his belief that the increase of yield obtained by Messrs. Riley and Talbot might be considerably improved upon, and in proof of that he would point out that if 3.6 per cent. of carbon used in these experiments were taken, they would find by calculation that they ought to get a theoretical increase of no less than 14.6 per cent. of iron from the carbon alone, and that was in contrast with the actual 5 per cent. that Mr. Talbot had obtained. So that there was still a very large margin for improvement; but no doubt Mr. Talbot's invention was the greatest advance that had been made in this direction. It need hardly be pointed out that increase of yield was only one result of the reaction process. Rapidity of action was equally important. Indeed, one of the difficulties of carrying out the reaction process to its fullest extent was that the action was so vigorous as to be explosive in its suddenness. It was clearly pointed out by Mr. Talbot in his paper, that "an immediate very active reaction takes place, during the continuance of which the gas is cut off from the furnace. The reaction has all the characteristics of the Bessemer blow during the elimination of carbon, a large volume of carbonic oxide being given off, which immediately ignites and burns with an intense flame, the heat thus produced partly raising the temperature of the bath, and partly being absorbed by the regenerators." He would like to ask the author of the paper, in connection with that point, whether all the carbonic oxide given off at that stage of the proceedings was really burnt in the

furnace, or whether the analysis of the flue gases given off at that point revealed the presence of free carbonic oxide. He was inclined himself to think that in all probability a good deal of this carbonic oxide might escape. Another result of the reaction process was that an increase of temperature was produced in the bath. This could be proved by theoretical calculations of the thermal units of the materials under employment. A further valuable saving was made in the cost of ferro-manganese and other reducing agents employed. He would like to point out that this was a very remarkable point, and it was not quite clear to his mind how it occurred, but it did seem to him that if they attempted to decarburise molten iron with oxide of iron there must be a limit at which the action ceased, whereas if they decarburised and desiliconised pig iron by air, they could go on *ad infinitum*, as was proved by the brown smoke that came off from the converter when the vessel was on its side. That was, they might burn the whole of the iron away, but they could not do that when they used the reaction process between the oxide of iron and the molten iron. There must be a limit, and it occurred to him that probably that had something to do with the saving in the ferro-manganese. Then, with regard to the use of scrap, Mr. Talbot had suggested that the cheapest mode was to re-melt it in the blast-furnace. He could not agree with him there, because he thought that Sir Lowthian Bell's investigations had shown that the blast-furnace was not an economical melter of anything. Seeing that they did not get anything like the full value of the fuel employed, he thought probably it would be found to be cheaper to melt the scrap in a cupola. A large quantity of scrap might be melted in the cupola along with a moderate amount of pig iron, certainly up to 50 per cent. of the charge. Therefore, he thought the cupola might be very well used as an adjunct in this process, rather than put the scrap metal through the blast-furnace. Then, with regard to the removal of slag, he thought the furnace employed by Mr. Talbot was a most ingenious one, and that it lent itself very well indeed, as was quite evident, to the removal of the slag at a given point; but he would like to ask Mr. Talbot how far he went in that removal of slag. He (Mr. Talbot) showed that a certain portion of the slag was poured off, but he (Mr. Snelus)

thought that it would be found to be an advantage to get the slag from the iron as much as possible. It was quite clear that if a considerable quantity of slag were left in the furnace, and then oxide of iron were put in, it diluted that oxide of iron to such a point that it had not the same effect as it would have if it were in a more concentrated form, and therefore the more slag that could be removed from the furnace the better. In studying the paper in question, he had been very much struck by the clear way in which Mr. Talbot had deduced the essential conditions of success, as shown in his paper, and he would like very much indeed to bear his testimony to these points as being most important. These points, he says, are—"The use of fluid metal from blast-furnace, mixer, or cupola, to avoid loss of time and oxidation by air during melting in the Siemens furnace, and to utilise the heat of the molten metal. The oxidation of the metalloids should be effected entirely by means of solid oxides of iron, and not by the action of the air." He (the speaker) could not too strongly emphasise that point. He considered it of the utmost importance, and that Mr. Talbot's furnace afforded the means of doing it to the best extent at present known. Then the paper went on: "Maintaining by some suitable means a large reserve of heat to keep the oxidising slags and metal in a fluid condition, and to ensure the rapid removal of the metalloids from the molten pig iron." That was, to his mind, a most important point, and the man who had had requirements so clearly in his mind was on the right road to success, and he (Mr. Snelus), for one, congratulated Mr. Talbot very sincerely on the results which he had produced. He deserved the best thanks of the Institute for having brought the paper before them.

The PRESIDENT said that they had Mr. Ambrose Monell, of the Carnegie Steel Company, with them, but as he was hoping against hope that Mr. Andrew Carnegie would be with them very soon, he would call upon Mr. Monell a little later. In the meantime he would ask Mr. Wellman, inventor of the Wellman tilting furnace, whom all would remember, to address a few remarks to them.

Mr. S. T. WELLMAN said he was very glad to be present on that occasion and to address the meeting, and especially to congratulate Mr. Talbot, not only on the courage which he had displayed in performing his experiments on so large a scale, and being the first to build a 75-ton furnace, but also on the success which he had obtained in carrying out his experiments. He (the speaker) had been away from America for the last three months, and therefore had not been able to follow out the details of the process, but he had gathered from what he heard from his associates that Mr. Talbot was obtaining all the success that he claimed, and that the results were extremely encouraging. He had not the slightest doubt but that the process of the future in open-hearth metallurgy would be the use of fluid metal direct from the blast-furnace in some form or another, and he again wished to congratulate Mr. Talbot on the success he had obtained.

Mr. THOMAS JINKS (Pencoyd, U.S.A.) said he could only confirm the statements that had been made, where Mr. Talbot spoke of the adaptability of the furnace for supplying the metals and improving their quality. He could testify to the improved results obtained by getting the supply as it was wanted in the mills, and also to the better quality of the metal.

Mr. E. P. MARTIN (Past-President) said that during his last visit to the States in 1897 he had the advantage of studying Mr. Talbot's wonderful invention, and since that time Mr. Talbot had kindly communicated to him results of tests and trials that he had made. He had since had the opportunity of making certain trials at Dowlais, and all he could say was that, as far as those trials went, they confirmed in every respect the statement made in Mr. Talbot's paper. He was strongly of opinion that they were on the eve of very great changes with regard to the Siemens furnace, and that before long they would be obliged to make another great change in all their plant. From his point of view the furnace of the future, on Mr. Talbot's plan, would have to be one of about 200 tons, coupled with a mixer of about 300 tons. The only drawback that he could see with regard to Mr. Talbot's process was as to what might happen should a break-out occur with 250 tons of molten steel. It was not

pleasant to think of. As far as he could judge, the process embodied one of the greatest advances that had been made in the Siemens furnace for the past five or ten years.

The PRESIDENT, in calling upon Sir Lowthian Bell to address the meeting, said that not only was his name mentioned in the paper, but his works were intimately connected with the progress that had been made in every direction, and he was sure they would not be content unless he offered to say a few words.

Sir LOWTHIAN BELL, Bart. (Past-President), would not detain the meeting by offering any opinion with regard to the process that had just been described by the writer of the paper, and by those who had taken part in the discussion. He did not say that, of course, from any disbelief in the correctness and soundness of the views that had been laid before the meeting, but he would rather ask them to attend for a moment to his experience at a further stage of the inquiry—namely, in regard to the character of the product. As one connected with a large railway in the country, he had been for the last half-dozen years almost unremittingly employed in ascertaining the behaviour of the rails after they had left the works of the manufacturer. He referred to the rails made by the ordinary Bessemer process; and whether it was from the impossibility of securing uniformity of conditions either in the manufacture of the iron itself or of dealing with it in the converter, he was not prepared to say; but on one point he was perfectly certain—namely, the extreme irregularity of the material as produced in the Bessemer process. Among other inconveniences connected with that mode of dealing with iron was the rapidity of the operation. There was no time to examine the product, either during the blowing while it was going on, or immediately after it had ceased, the consequence being that a product was obtained which was most irregular in its character. He had during the last five years been much engaged in that inquiry, and it would have been almost impossible, if he had not verified the matter over and over again, to bring before them with sufficient clearness the extent of that irregularity. He was surprised that from the same converter charge he had had differences in the power of resisting fracture in the rails so made to the extent

of 100 per cent. By that he meant that the number of the blows required for producing fracture in a rail obtained in the same converter charge might be only twenty, whereas in other cases it would stand 200. He thought that the open-hearth steel, from its deliberate mode of action and the time required in its accomplishment, was such that the measure and character of the product could be taken, and it could be either advanced or, if it was thought that they had gone too far in one direction, it could be brought back and brought to the same condition that obtained a certain number of minutes or hours before. Under those circumstances he had been led to believe that the time was not far distant—if, indeed, it had not already arrived—when they would have to abandon the Bessemer process entirely, and substitute for it the open-hearth mode of producing steel. In that process they had abundant opportunity of seeing what was being done, and they could test the steel in an unmistakable way, and determine upon the results accordingly. He had had much pleasure in listening to the papers read, because they dealt with the question that had occupied him for several years past; and he had said in this very room not long ago that until they were able to make steel rails by a slower and more manageable process than that of Bessemer, they would fail in satisfying the urgent requirements of the present day.

Mr. R. M. DAELN (Düsseldorf) said that, with regard to the paper of Mr. Riley, he thought that the true reason why the open-hearth furnace had not been so much used hitherto to refine pig iron was its inferiority in the capacity to refine, and that drawback would always remain the same for the open-hearth furnace. Many different methods had been tried of overcoming that drawback, and as the Bessemer converter was the most energetic and best apparatus for refining, he was sure that what was called the duplex process would be the process of the future. It was only a question of refining in the converter in a very cheap and simple method, and he thought that this was done now in the method proposed by Mr. L. Pszczolka in Vienna and by himself, by taking the fluid metal directly from the blast-furnace into a side-blown converter, fixed or tilting, and blowing it over by hot air from the existing blast-engine. That was the method adopted

at Krompach in Hungary and at Czenstochau in Russia, and it would be carried out next in two places in Germany. In his opinion it was worth while reading to them a paper on that process, but as it had not been carried out except in a tentative way, not to any large extent, he would wait till it had been tried further. There was no doubt that, from a technical point of view, the process was successful; but at Krompach, where they had as yet only one blast-furnace for a large open-hearth steelwork, there was not enough liquid pig iron to do it in a regular way, but it had been proved by all they could see that the process was a very successful one. The only point which was cited as not quite fixed was the question of the loss of iron by blowing by hot air. The weight of the pig iron could not be determined between the blast-furnace and the converter; it was made afterwards when it was over-blown and before it was poured into the open-hearth furnace. Then the slag being dealt with and an analysis taken of the slag, it was found that altogether the loss was not more than 7 per cent. by over-blow. But it must be said that the pig iron of Krompach contained merely about 2.5 per cent. of manganese, and that high percentage would not be necessary for the process. It would be only necessary to have 1 per cent., so that $1\frac{1}{2}$ per cent. must be found of that high percentage of manganese, and there was only 5.5 per cent. of loss in the over-blow. Then in the open-hearth furnace they had again 6 to 7 per cent., and that would give altogether about 13 per cent. of loss of iron. He did not think any one could call that very much, because in the Bessemer process it was the same, and in the Siemens-Martin process, when melting scrap and pig iron only, it was always 9 or 10 per cent. The good yield pointed out that morning by Mr. Riley and Mr. Talbot was due to the iron ore put into the open-hearth process. With regard to the paper of Mr. Talbot, he could not see any profit in installing a very large open-hearth furnace of say 100 or 200 tons, and using it only as a very small furnace of 30 or 50 tons. For instance, at Pencoyd, the open-hearth furnace was a 75-ton one, but it was used only as a furnace of 20 tons. He thought that was a very expensive installation in which such a big furnace was put up, when for the same cost he could get several more simple open-

hearth furnaces of 30 tons, and they would certainly have the same capacity as that very large furnace of Mr. Talbot's. In Germany they got with a 20 or 30 ton furnace up to five or six charges in twenty-four hours, when melting much scrap with little pig iron. They had less charges when taking more pig iron, and he thought it always the best way to refine the pig iron before putting it into the open-hearth furnace. He believed also in having a very large quantity of liquid steel in an open-hearth furnace, which should remain there a very long time in order to be what was called dead molten. A considerable time after the process was finished was required in order to light the fires and melt it thoroughly, as was done in the crucible. If that was done with a very large quantity, it always required a very long time. Then afterwards, if the bath was ready, only a third or a quarter of it would be taken out, and then he would have to add pig iron again and recommence to refine and also to melt that large quantity thoroughly in order to obtain the best quality. Both points required very careful attention before deciding upon one or the other process, and it was not possible to judge really between the one or the other without having all the figures as to the cost of the process before them. Mr. Talbot, however, had said that he could not give the exact figure for the amount of coal required, and he (the speaker) thought that was the principal thing, because it had been found in the Siemens-Martin process that as more coal was used there was more wear and tear of the furnace going on; and there was no doubt that as more charges in twenty-four hours could be run out, less coal was used. In Germany they came down to 25 per cent. of coal in the output of steel, and in the duplex process they came down to 15 to 20 per cent. of coal. There was not only a loss of coal, but of all the other profits they got in what went on in the same way in the wear and tear of the furnace. He thought it would be important to have more exact figures about the process before they could judge of it.

The PRESIDENT said that they were very much indebted to Mr. Daelen for his valuable remarks, and he hoped they would have the paper he had promised for the Paris Meeting. He would now call upon Mr. David Evans, whom they rejoiced

to see at the meeting after his recent illness, to say a few words on his experience of the duplex process.

Mr. DAVID EVANS (Member of Council) said that at Bolckow, Vaughan, & Company's works they had introduced the duplex process a short time ago, with the object of trying to get over the irregularity they all knew of in the Bessemer process. To meet that, they had introduced the duplex process to desilicise, and then they had to take the metal quickly into the Siemens furnace, and to give it proper time to test it thoroughly, so as to know exactly what it would do before it was taken out. They carried these experiments on for some time, and they found that the yield was rather against them. That was the greatest drawback, but he thought that, with better appliances and quick transit, and a better mode of dealing with it than they had, there was some future for it. The great point was to have proper machinery to deal with it quickly after it was blown and to keep the converters continually going, and to have a large number of furnaces to take the metal as it was blown. He believed there was a future for it himself. He did not conduct these experiments, but they were conducted under the charge of Mr. Arthur Richards, who was then present, and who would be able to give some further information on the point.

Mr. AMBROSE MONELL (Pittsburg) said that the papers of Mr. Riley and Mr. Talbot were very interesting, and certainly deserving of most careful consideration. With regard to Mr. Riley's paper, he would leave the discussion to those who were more familiar than he was with the acid open-hearth process. Mr. Talbot's process involved certainly a radical change from any previous method of operation, but it had several serious disadvantages. However, in order that any criticism of his might be clear, it would be necessary to describe briefly the process he had introduced at the Homestead Steelworks of the Carnegie Steel Company, by which they were producing from pig and iron an output of from 650 to 720 tons of steel per week with a single 40-ton furnace. His description would be most concisely done by giving them the substance of a paper he had specially prepared on the subject.

The memoir communicated to the meeting in abstract by Mr. Monell was as follows:—

Before taking up the description of this pig and ore process, I wish as an introduction to call attention to some few developments in metallurgy, which in a manner lead up to and have a bearing on the subject.

It is not my intention to describe the various processes mentioned, but simply to cite them as they have reference to the particular case under discussion, and in order to draw comparisons.

In view of the fact that the commercial value of an open-hearth plant is so largely dependent on the amount of steel produced in a given time, the object of steel-producers in general has been to shorten the time of individual heats as much as possible, thereby securing the maximum output. It is understood, of course, that in shortening the process the value of increased production must not be overbalanced by the increased cost of operating.

In modern open-hearth practice the method of operation usually adopted, as having the greatest advantages in regard to speed and economy, is to charge a certain percentage of steel scrap together with the pig, ore, and limestone, the weight of the scrap being, roughly speaking, from 40 to 60 per cent. of the entire charge. A 40-ton basic open-hearth furnace charging 50 per cent. cold pig and the balance scrap will average fourteen heats per week (six days).

The use of molten pig instead of cold pig, in the same type of furnace, will still further shorten the time of the heat, and when the pig can be obtained in this condition, the method of operating is to charge the scrap (50 per cent.) with the ore and limestone, and bring them to what is known as a "sweating" heat. The molten pig (50 per cent.) is then charged. With this method sixteen heats would be an average week's run.

Still having as an objective the reduction of time for a heat, numerous "double furnace" processes have been tried, the best known of which is the Bertrand-Thiel. This process is, in short, to charge the pig, ore, and limestone in the primary furnace, the hearth of which is somewhat above the level of the secondary or finishing furnace. The secondary furnace is charged with scrap and limestone, and sometimes a little ore. The pig in the

primary furnace is melted, partially purified of the metalloids, and brought to a high temperature. When the scrap in the secondary furnace has reached a sweating heat, the primary furnace is tapped, flowing down a runner into the secondary furnace, the slag being skimmed off in transit. The average time the charge is in the primary is four hours, and, after mixing, the metal is in the secondary two hours. By this method five 23-ton heats are made every twenty-four hours with two furnaces, which would be 690 tons per week. This is not remarkable, as at the Homestead Steelworks 600 to 650 tons per week are made with a single 40-ton furnace.

We therefore return to the ordinary pig and scrap process, using either cold or molten pig, as being the most rapid and economical at the present time. This process entails the use of scrap; and the necessity of using steel scrap in order to obtain a reasonable output per furnace has been a serious limitation in the production of open-hearth steel, as steel scrap is often expensive and difficult to obtain.

As the use of scrap is often a serious disadvantage, it naturally follows that many attempts have been made to dispense with it entirely, and produce steel from pig and ore. Several of these processes have been more or less successful in respect to the quality of steel produced, percentage of product, action on the furnace, &c., but none, to the best of my knowledge, have produced with a given furnace even approximately the same tonnage as said furnace would have produced had it been run on pig and scrap.

There are three processes for the production of steel from pig and ore that I wish to mention.

1st. The ordinary practice of charging cold pig together with ore and limestone, melting down the same, then thinning the slag if necessary with fluorspar, and reducing the carbon with successive ore additions. With a 40-ton furnace this takes about twelve hours to a heat, and eleven heats is an average week's run. Therefore this process is expensive, as it means a serious decrease in product when compared to running the same furnace on pig and scrap.

2nd. The combination Bessemer and open-hearth process, which was for a time in operation near Middlesbrough. This

method was to charge in an acid converter 12 tons of low phosphorus, high silicon pig, eliminate the silicon and manganese, and reduce the carbon to about 0·5. Two blows were then run into a 25-ton acid open-hearth furnace, and in two hours the carbon was reduced to 0·10. At Witkowitz, where the pig obtainable contains too much phosphorus to be used in the acid Bessemer, and not sufficient phosphorus for use in the basic Bessemer process, the operation is as follows:—Pig iron containing about 1 per cent. silicon is run from the blast-furnace into a ladle and transferred to an acid Bessemer converter, where the pig is desiliconised. The desiliconised metal, still containing some manganese and considerable carbon, is poured into a ladle and transferred to a basic open-hearth furnace, where it is dephosphorised and decarbonised. In these combination processes the loss is naturally very heavy, due to the large loss in Bessemer practice, and there is also the cost of maintaining two plants.

3rd. The Talbot continuous open-hearth process, previously described, which has been in operation since last September at the works of the A. & P. Roberts Company, Pencoyd, Pennsylvania. On reading a detailed description of this process, it will be noted Mr. Talbot depends for rapid and successful operation on the oxidising effect of an extremely basic slag, which is enriched from time to time. With the Talbot process 500 to 530 tons of steel have been produced per week from pig and ore.

Laying aside the question of amount of steel produced by this process, there are still some serious disadvantages, as, for instance: The first cost of a furnace of this size and type must be large, and also it would be extremely inconvenient, if not impracticable, to run the Talbot furnace on a pig and scrap process should the price of scrap make a temporary change advisable. The furnace additions being small and at frequent intervals, while not a serious difficulty in the operation of a single furnace, would be extremely cumbersome in the operation of a large plant. Further, it would be difficult, if not impossible, in the Talbot process to tap anything but dead low steel, which prevents the manufacture of any steel by this process which is too high for recarbonisation.

To return to the ordinary pig and ore process, in which the cold pig is charged with ore and limestone. The great objection to this process is the length of time required to make a heat, *i.e.*

about twelve hours. This is due to the excessive amount of impurity to be removed, and to the heavy slag formed, which prevents the proper action of the flame on the bath. The product with a 40-ton furnace would be eleven heats per week, or about 420 tons, which means a decrease of 150 to 200 tons per furnace.

The process I am now about to describe avoids the above-stated objections, and enables the manufacturer, if he desires to do so, to dispense with steel scrap, or to greatly reduce the percentage of scrap in his charge; and it enables the process, with the use of pig and ore, to be carried on as rapidly and economically, and with as great an output per furnace, as with charges containing 50 per cent. of scrap.

The process consists in charging in a basic open-hearth furnace limestone and a relatively large quantity of ore, heating these, and then charging molten pig metal taken from a mixer or direct from the blast-furnace. The temperature of the resulting mixture must be sufficiently high to produce a rapid slag formation, and yet low enough to ensure the rapid oxidation of the phosphorus. The slag formed rises in a foam and is drawn off at a cinder notch. One hour after charging the molten pig the bath is practically free from phosphorus, silicon, and manganese, and the bulk of the slag containing the impurities has been removed. The bath is then in the best possible condition to be acted on by the flame and remaining ore which has not yet been reduced. The steel may be tapped when the carbon has reached the desired point. Either mill scale or tap cinder may be substituted for the ore, and the proportion of oxide may be varied according to the percentage of carbon desired in the finished product.

At the Homestead Steel Works of the Carnegie Steel Company two furnaces have been making steel by this process since February 18, 1900, the operation in detail being as follows:—

A 40-ton basic furnace of the ordinary solid-hearth type is employed, the inside dimensions being 12 ft. 6 in. \times 26 ft. 4 in. and the area of the checkers 4000 cubic feet. The stack has an outside diameter of 6 ft. and a height of 140 ft. 6 in. A dolomite bottom is used, and the banks are made up of the same material.

A cinder notch at least 6 inches wide is cut in the back of the furnace, and the height of the notch is about 4 inches above the level of the bath when the furnace is first charged. A cinder

pit, in which hooks are placed in the usual manner, is located at the back of the furnace, and as near as possible to the cinder notch; this arrangement of cinder notch and cinder pitch being the only changes made in the furnace.

The first charge is 6500 of limestone, which is distributed over the bottom, and then 22,000 to 26,000 of ore are added, depending on the silicon contents of the iron to be used. The ore employed is a red hæmatite from the Lake Superior region, having the following analysis:—

Fe.	P.	Si.	Mn.
64 per cent.	0·1 per cent.	3·00 per cent.	0·1 per cent.

The ore and limestone are heated for about an hour and thirty minutes, at the end of which time the ore is on the verge of fusion, but not necessarily fused.

The preliminary charge is now in a condition to receive the molten pig, which is obtained either from a mixer or direct from the blast-furnace, the analysis of the pig being as follows:—

C.	P.	Si.	Mn.	S.
3·90 to 4·10	0·50 to 0·80	0·50 to 0·90	0·80 to 0·90	0·04 to 0·07

88,000 lbs. of metal are now brought in two ladles and charged in the furnace, the temperature of the metal being comparatively low—that is, not necessarily higher than when tapped from the blast-furnace.

After making the above addition of metal, the reaction in the furnace is sharp, but not violent. The materials being at a comparatively low temperature, the phosphorus is oxidised with extreme rapidity, together with the silicon and manganese, and a portion of the carbon is at the same time oxidised. This is accompanied by a rapid production of basic slag. At the end of one hour, more or less, the phosphorus will have been substantially eliminated from the metal—that is, reduced to less than 0·04 per cent., together with the silicon and manganese. As the slag formed by these reactions boils up, it is allowed to run off through a cinder notch located in the back of the furnace, and kept as near the level of the metal as practicable, the slag running into a pit in which hooks are placed, and the slag is cooled and removed in the usual manner. The removal of the slag is finished within an hour from the introduction of the molten

metal, and is as complete as possible. In practice it will be desirable to remove about 80 per cent. of the entire body of the slag, leaving the bath of metal nearly uncovered.

At this time—*i.e.*, one hour—after adding molten metal, the slag which has been withdrawn and the metal show approximately the following analyses:—

SLAG.		Per Cent.	METAL.		Per Cent.
SiO ₂	. . . .	20	C.	. . . .	2·00-2·50
Fe	. . . .	20-25	P.	. . . .	0·04 or under.
P ₂ O ₅	. . . .	3-5	S.	. . . .	0·04 or under.
CaO	. . . .	20-25	Si.	. . . .	Practically none.
			Mn.	. . . .	" "

By these operations the metal is dephosphorised while the metal is still at a relatively low temperature, which is the condition of temperature most favourable for that purpose, and the phosphorus and silicon-bearing slag is removed from the furnace at an early stage of the process.

Although the metal is dephosphorised by the operation described above, and the phosphorus removed from the furnace when the slag is withdrawn, the decarburisation is not completed, that is, the carbon is not reduced below 2 per cent. when the slag is removed. The removal of the slag, however, leaves the surface of the metal nearly uncovered and in the best condition to be rapidly heated by the flame.

The slag having been withdrawn, the bath is heated as rapidly as possible, the ore remaining in the furnace, together with the action of the flame, reducing the carbon with great rapidity.

It is generally necessary to charge a few hundred pounds of ore just before tapping, in order to bring the carbon to the desired point, as the original ore charge is so estimated as to prevent the bath melting low.

The carbon having been brought to the desired point, the operation is the same as in ordinary practice.

The following is a report by heats of a two weeks' run.

The charge in every case was 6500 tons of limestone and 22,000 to 26,000 tons of ore or tap cinder depending on silicon in the pig.

The molten pig employed contained—

C.	P.	Mn.
3·80 to 4·10	0·5 to 0·8	0·80 to 0·90

CARNEGIE STEEL COMPANY, HOMESTEAD STEELWORKS.

Record of Pig and Iron Ore.

Heat.	Pig Iron.	Total Product.	Product in Percentage of Pig Metal Charged.	Time of Heat.		Analysis of Pig Iron.		Ladle Analysis.			
				Hrs.	Mins.	Si.	S.	C.	P.	Mn.	S.
1	89,500	95,160	105.6	11	10	60	.052	26	.012	37	.019
2	90,400	93,810	103.0	8	30	63	.043	26	.017	40	.021
3	87,400	89,240	101.1	7	55	55	.037	24	.015	37	.020
4	88,900	93,910	104.9	7	45	57	.040	26	.011	35	.020
5	88,900	91,610	102.0	9	0	60	.033	26	.017	42	.026
6	87,500	93,710	106.3	8	50	46	.049	26	.020	39	.024
7	93,900	97,260	102.9	7	55	41	.050	24	.017	36	.020
8	91,100	94,610	103.0	6	55	50	.059	27	.012	36	.023
9	85,600	92,990	107.8	7	10	60	.025	23	.011	37	.021
10	87,600	94,960	107.6	8	20	40	.042	24	.017	35	.021
11	87,900	91,540	103.2	7	35	55	.034	23	.012	38	.023
12	90,500	93,710	102.8	8	15	50	.019	26	.017	35	.018
13	93,500	93,410	99.2	8	5	38	.074	24	.011	35	.019
14	88,200	91,440	102.8	9	5	65	.059	24	.017	37	.021
15	88,560	87,940	98.6	9	5	92	.024	26	.015	43	.027
16	88,200	87,170	98.1	7	40	63	.045	22	.014	43	.026

Number of
Heats made
during Week.

16

Product
in
Tons.

662

Product in
Percentage of
Metal Charged.

103.1

Average
Time
per Heat.

8 hrs. 20 mins

Record of Pig and Ore Heats.

Heat.	Pig Iron.	Total Product.	Product in Percentage of Pig Metal Charged.	Time of Heat.		Analysis of Pig Iron.		Ladle Analysis.			
				Hrs.	Mins.	Si.	S.	C.	P.	Mn.	S.
1	88,400	91,510	102.8	9	50	72	.028	23	.017	34	.025
2	88,000	89,640	101.1	9	0	52	.068	23	.017	44	.025
3	86,400	90,610	103.8	8	10	40	.050	19	.017	40	.023
4	89,200	82,420	91.5	6	50	26	.050	24	.014	43	.025
5	88,400	94,810	106.2	9	50	55	.036	23	.015	40	.028
6	86,400	90,490	103.9	8	0	85	.033	27	.012	40	.023
7	87,000	91,640	104.6	7	40	60	.050	25	.016	40	.025
8	88,500	91,010	101.8	8	10	70	.044	25	.015	35	.028
9	88,600	90,240	100.5	6	50	65	.034	27	.017	40	.022
10	88,600	90,540	101.5	7	40	51	.049	23	.014	40	.020
11	90,500	93,010	101.9	7	20	53	.068	28	.016	40	.023
12	87,400	87,790	99.6	6	8	67	.059	26	.015	39	.021
13	88,500	91,540	102.7	6	5	68	.050	29	.016	38	.024
14	88,000	87,440	98.5	6	40	45	.046	26	.017	39	.021
15	86,500	82,150	94.1	6	20	68	.050	28	.011	45	.021
16	88,000	87,750	99.0	8	15	56	.034	21	.021	42	.023
17	87,800	91,260	103.2	8	35	72	.024	15	.015	40	.024
18	88,500	84,260	94.8	6	25	55	.053	15	.012	35	.027

Number of
Heats made
during Week.

18

Product
in
Tons.

718

Product in
Percentage of
Metal Charged.

101.3

Average
Time
per Heat.

7 hrs. 39 mins.

It will be seen that thirty-four heats were made during the two consecutive weeks' run, the average time of a heat being eight hours, and the steel produced 1380 tons. There is also a material gain in product due to the iron reduced from the ore.

The chemical composition of the metal that has been used in this process has varied in carbon, phosphorus, silicon, and sulphur, while the manganese has remained practically constant. With the pig employed thus far, the only constituent, a variation in which seems to affect the time of the heat, is the silicon; in general, the best results being obtained with silicon running 0.6 and under.

The important factors in this process are:—

1. The proportion of iron oxide charged must be sufficient to dephosphorise the pig at an early stage in the process, and the amount of limestone must be sufficient to form a heavily basic slag in order to hold the eliminated phosphorus.

2. The temperature of the mixture after the addition of the molten metal, which must be low enough to allow of the complete oxidation of the phosphorus, and high enough to produce a sharp reaction and a rapid slag formation.

3. The removal of the major portion of the slag from the furnace at an early period in the heat, thereby increasing the action of the flame on the bath, and also preventing the possibility of the phosphorus returning into the metal.

In reference to the temperature of the hot metal used in this process, it would appear that the temperature of the metal itself is not the important factor, but the temperature of the mixture after the addition of the molten metal to the ore and limestone. As has been mentioned, the ore and limestone are heated for about an hour and a half before adding the molten metal, and under these conditions satisfactory results can be obtained with metal at a comparatively low temperature. If, however, the metal were previously heated to a high temperature in a suitable mixer, it might be possible to dispense with the preliminary heating of the ore and limestone.

The advantages of this process are as follows:—

1. The use of scrap may be discontinued, if deemed advisable, and steel produced from pig and ore without either a decrease in tonnage or an increased cost.

2. It is possible in an ordinary basic open-hearth furnace, equipped to receive the molten pig, to produce from pig and ore, with less fuel, as large a tonnage as from pig and scrap.

3. In a plant already equipped to handle molten pig the operation of charging a furnace is both shortened and cheapened.

4. By practically removing the phosphorus from the pig while the carbon is still 2 per cent. or more, it is possible, without reducing the output, to produce a low phosphorus steel of any desired carbon from either a high or low phosphorus pig.

Mr. M. MANNABERG said, that so far as he could follow Mr. Monell's paper it seemed that the process described was nothing else than the Talbot steel process in a fixed furnace of smaller capacity. By using the Talbot furnace it would be possible to dispense with a mixer, because a Siemens furnace with a capacity of 100 or more tons would act as a mixer. Mr. Monell would undoubtedly get large makes per week per furnace, but the great advantage of the Talbot furnace seemed to be that, in addition to large makes per week, the makes were cast in smaller units, and supplied to the mills at very regular intervals. That meant a less costly plant in the shape of cranes for dealing with the casts, and more hot ingots at the mill, a point which every steelworks manager would appreciate. Where Mr. Monell cast 40 tons, Mr. Talbot cast two lots of 20 tons each. The yield of the Talbot furnace was unsurpassable at present. Mr. Monell spoke of a best yield of 102 per cent., whereas Mr. Talbot had established 106 per cent. over a period of six weeks, and had even reached 107 per cent. in exceptional weeks. It was not stated by Mr. Monell what the coal consumption was. Mr. Talbot stated from 3 to 4 cwt. per ton of steel made, which was quite likely, considering that Talbot's furnace was kept at a constant high temperature during the whole week, never appreciably cooling down, and that his reactions were so very rapid. The bottom of Talbot's furnace would also stand better than that of Mr. Monell, or that of any other furnace which was completely emptied after each cast. The heavy reactions which took place in Talbot's 75-ton furnace at Pencoyd were entirely surface reactions on the surface of the steel bath, the deeper layers of the steel bath remaining quiet. An important point in Talbot's process was that he

made use of the difference in specific gravity of pig iron and steel. Talbot's furnace bottom had to stand solely the quiet molten steel for the whole week, and was not exposed to any corrosion by oxides or slags. This was plainly seen when Talbot's furnace was emptied at the week end, when the bottom was in perfect condition, and only round the slag line did the bottom show corrosion. From a practical furnaceman's point of view, it seemed easier and less dangerous to handle a 100-ton Talbot charge than a 40-ton Monell charge, and to prove it he had arranged to put down one of Talbot's furnaces.

Mr. F. W. HARBORD said he would like to refer to one or two points raised by Mr. Daelen. He said that in desiliconising in the Bessemer his loss in yield was 7 per cent., and taking it at this, which was much less than he himself had found in his experience in South Staffordshire, where they tried it some years ago, but gave it up on account of the cost, this meant a loss of seven tons of steel on every 100 tons made, against a gain of seven tons on the Talbot process, making a total difference of fourteen tons on every 100 tons of steel made. Practical steel-makers present knew far better than he did what this represented in cash at to-day's prices. Mr. Daelen had also raised the question of fuel, and Mr. Talbot in the appendix which had been handed in since the paper was printed, stated that he was able to give the results of one fortnight's work with the furnace on a separate producer before he left the States, and had convinced himself that from $4\frac{1}{2}$ to 5 cwt. of fuel per ton of ingots was the outside when working 33 per cent. charges, and he had obtained results showing less than 3 cwt. when working 10 per cent. charges, but he did not wish the latter figure to be taken as absolute until he had been able to carry out a series of experiments over a longer period. Mr. Monell had described a process which he was surprised to hear him claim any novelty for, for oxides of iron and lime had been regularly charged into basic Siemens furnaces in every works in the country since 1886, and if members would refer to a paper he had the honour of reading before the Institute in 1886, they would find it very fully described there. He used large quantities of non-siliceous flue cinder, charged it on the bottom and then the pig iron, the only apparent

1900.—i.

difference between this and Mr. Monell's practice being that Mr. Monell charged fluid instead of solid pig iron.

The PRESIDENT said that any remarks by experts in Canadian metallurgy would be very acceptable to them, and as Mr. Graham Fraser, of the Nova Scotia Steelworks, Nova Scotia, was present, he hoped he would give them the benefit of his views.

Mr. GRAHAM FRASER said that he happened to be present then for the first time, and he would just say that, after investigating Mr. Talbot's process for the Nova Scotia Steel Company, with which he had been connected for some twenty odd years, they decided to put in one of the furnaces and make the experiment of working it. They contemplated putting in four or five more furnaces later on. They had ordered the one to which he had just referred, and they hoped to have it working in June. He did not know that he could add very much to what had already been said, but he might say that, respecting Mr. Talbot's continuous process, he was always frightened of the hearth not standing the wear, but after seeing the furnace emptied out at the week end after doing its work, and seeing that it was in perfect order, very much to his surprise, that objection had been overcome. After his visit he had sent the manager of the smelting department to study it with Mr. Talbot, and to see the furnace working, and by what the manager reported he felt warranted in adopting the furnace. The furnace adopted for the first trial was a 50-ton furnace.

Mr. J. RILEY, Vice-President, in replying on the discussion, said he wished to add his testimony to the value of the results of the Talbot process. He looked upon the paper when he read it as one of very great interest, and if the facts stated therein could be substantiated, he took it that Mr. Talbot had initiated a revolution in open-hearth practice. That was his view of it. It was a paper which would bear a very great amount of consideration and study. It bristled with points which were attractive to steel-workers, and these points were set forth in the recapitulation at the end. But there were a number of points mentioned

incidentally which were of importance, as, for instance, that any grade of pig iron within reasonable limits could be used, which, if found to be correct in practice, was a valuable feature in the process. Then, inferentially rather than prominently stated, was one important point, which enabled them to dispense with mixers, and, more than that, it enabled them to dispense with the duplex process, which he (the speaker) had mentioned in his own paper. The duplex process could only be an advantage where they were dealing with pig with silicon up to a high percentage, which they usually had in the open-hearth process. Then it would be a great advantage, but with the dilution which Mr. Talbot was able to carry out, apparently he could dispense with the duplex process. There was no mention made of the extent of the reduction of cost. Inferentially there was given one means of estimating this reduction. If their friends could afford to bear the high cost of pre-melting in a cupola, and yet find the process profitable, it was evident that there must be very considerable economies in other directions. The paper was altogether satisfactory to him, because it confirmed many of his conclusions, although not all. They were at issue as to working the open-hearth furnaces with fluid metal and as to the matter of the damage to the hearth. Mr. Talbot had said it was admitted the hearth was damaged, but they had not found it to be so to any extent. Then he wished to refer to the question of the yield. He had spoken of 100 per cent. of the yield as obtained by them, and he had produced a statement which was a very gratifying one to the speaker. Mr. Talbot stated that he had a yield of 106 per cent., but there was a very considerable difference in the two methods of calculation. Mr. Talbot had included yield of ingot plus scrap, whereas he (the speaker) had spoken of ingots only. If they took away the scrap, they would find that Mr. Talbot's yield verified his statement. In one case it became 101½, and in another it was about 102 per cent. Then they had to bear in mind that that was worked by the basic process, whereas theirs was worked by the acid process. Then in the Talbot process the yield was increased by the addition of cinder and scale, which they were unable to use in the ordinary acid furnaces. He would not detain them longer, although he had a number of points that he wished to refer to. These were

perhaps the most prominent, and, in conclusion, he wished to congratulate Mr. Talbot on the success he had obtained and on the courage he had shown. He believed he had done a very great thing, which would be heard of again with great interest.

Mr. B. TALBOT, in replying, said that he had made a few notes while Mr. Riley was speaking, in order to answer some objections and for the purpose of giving information. Mr. Snelus had asked about carbonic oxide gas, and he had questioned whether it was all burnt in the furnace. He did not think so himself, because the regenerators were full of flame, and that was so throughout the period of reaction. It was probable, therefore, that it was not all burnt in the furnace, but partly in the furnace and partly in the regenerators. With reference to the quantity of slag removed, they must bear in mind that the covering of slag on the bath was very thin in the case of a 75-ton furnace when it was full up. Sufficient slag had only to be provided to purify the percentage of the charge of metal added each time, the other portion being purified and not requiring any basic additions, and consequently less basic additions, oxides, &c., were necessary when smaller additions of pig metal were worked. Generally the greater portion of the slag was removed after the first reaction, but this was entirely in the hands of the melter who was in charge of the operation, and sometimes, if it was found that the slag was sufficiently basic, the melter would not remove any until near the end, and he would then only take out a portion. Mr. Martin had alluded to what would happen in the event of a 200-ton furnace giving way, but they must bear in mind that they had what he called plenty of armour-plating, both in the bottom and on the sides round the slag line. Underneath the bath was 18 inches of solid magnesite brickwork, and on the top of that there was 12 inches of fused dolomite. If there were danger of the metal getting through that dolomite bottom, they would have ample warning, because the action of metal in a hole on the bottom of the depth of a foot would cause a corresponding motion on the top of the bath, and before the metal could seriously attack the 18 inches of magnesite the heat could be finished and the furnace emptied. As a matter of fact, during the eight months of working at Pencoyd they had

never had a single case of the dolomite portion of the bottom being cut away, and therefore he felt absolutely certain there was not the slightest risk of a break-out through the bottom occurring. The wear that took place on the slag line was absolutely under control, and if this was excessive at any one point, by tilting the furnace this portion of the lining could be exposed and readily repaired, or, if necessary, they could take 20 or more tons out, and so lower the level of the bath that the slag could do no further damage. In practice they had not even had to do this because the magnesite bricks in the wall were intact, and if they were looked at after months of working they would be found to be in perfectly good condition. Mr. Daelen said he preferred the Bessemer converter for refining. They knew the Bessemer converter was an excellent refiner, but it was a very expensive one, due to the fact that oxide of iron was produced at the expense of the metal itself.

Mr. Daelen admitted that the probable loss by the duplex system was 12 to 13 per cent., which, compared with the author's process giving a gain of 6 to 7 per cent., showed a difference of 18 to 20 per cent., which at present prices was a gain of from 15s. to 20s. per ton. Mr. Daelen also referred to the small amount of fuel used in his system, but had not said what amount of fuel was required to supply the blast. Now it was known that they could not get a blast for nothing, and they must put the amount of that fuel on to the top of that required in the finishing furnace operation. It had also been stated by Mr. Daelen that he could take a number of small furnaces and get the same output as from one larger one. So he could, but they could not run a number of small ones at the same cost as one large one. For instance, a 100-ton furnace could be run with five men at a given cost, but they could not run three 20-ton furnaces at the same cost, because the number of men would be more than doubled. It certainly was not the case, as stated by Mr. Daelen, that the 75-ton furnace was run as a 20-ton furnace, as although 20 tons was the amount of metal poured from the furnace at each tapping, that was simply a matter of convenience to suit the requirements of the mills to a large extent, and as they got four of such charges during the twenty-four hours against one full charge in ordinary practice, it

enabled a larger quantity of metal to be dealt with in the furnace with comparatively small ladle and crane casting-plant. The fact that the average output from the furnace was over 500 tons per week, working pig iron alone, disproved the statement that it was a 75-ton furnace doing the work of a 20-ton furnace.

With regard to Mr. Monell's remarks, they were somewhat difficult to follow, as instead of criticising the author's paper in the usual way, he had taken a somewhat unusual course, and elected to read, and would have read had time permitted, a somewhat lengthy treatise on basic practice in general and Homestead practice in particular. As far as he could gather, the latest practice at Homestead was to charge oxide of iron and limestone in the furnace before charging the metal, a practice which was about as old as the manufacture of basic open-hearth steel, and, as had already been mentioned by Mr. Harbord, was fully discussed in a paper before this Institute in 1887.

Mr. Monell had been at Pencoyd early in the year to investigate the speaker's process for two or three days, and he must congratulate him on having learned the value of preparing an oxidising slag before charging liquid metal into the furnace, and he had no doubt, when he had gained a little more experience at the Carnegie Company's expense, he would discover what had long been known to all practical men, that such oxidising slags had a most destructive action on the bottom of the furnace, and it was both advisable and necessary to protect the bottom from such action. Speaking of the size of his so-called 40-ton furnace, he (Mr. Monell) gave the dimensions as $12\frac{1}{2}$ feet by 26 feet, giving a surface area of 325 feet, whereas his furnace at Pencoyd, in which they had worked 70 tons, was only 30 feet by 9, giving an area of 270 feet, or 20 per cent. less than the 40-ton Homestead furnace. It thus transpired that the Homestead people were working 40-ton heats in a furnace, which with the speaker's process would have a capacity of 90 tons, and consequently with a furnace of such dimensions he would get an output by his process of from 25 to 30 per cent. more than obtained with his present Pencoyd furnace. This question of rating of furnaces as 40 or 50 ton furnaces when comparing the

ordinary Siemens process with his process was entirely misleading, as owing to greater depth of the bath of metal in the continuous process (which was not only possible but a distinct advantage), a furnace of the same dimensions would hold from 33 to 50 per cent. more metal than when working on the ordinary open-hearth system, and consequently a so-called 100-ton furnace was very little larger as regarded length and breadth than an ordinary 50-ton furnace.

Since the meeting he had had the opportunity of seeing Mr. Monell's contribution in print, and as the President had suggested that he should reply fully to this in writing, he would now deal with it more in detail.

In criticising the continuous process, the first point raised was the difficulty of dealing with scrap; but this largely existed in Mr. Monell's imagination, as scrap could be as readily charged into the bath as ore, and it was only a question of relative price of pig and scrap, and output and yield in a given time. As stated in the paper, the author, under normal conditions, considered it better to deal with the scrap in other ways, but there was no difficulty about using it direct if desired. Mr. Monell then stated that it was difficult, if not impossible, to make anything but low-carbon or dead soft steel, and the only charitable assumption to make was that Mr. Monell had not time to read the paper under discussion before criticising it, which was somewhat surprising considering that he made a special journey from the States to give the members of the Institute the benefit of his views. Had Mr. Monell taken the trouble to read the paper through, he would have seen it specifically stated that all grades of steel had been produced, from dead soft up to 0.30 and 0.40 per cent. carbon steel, and that this grade of steel could be produced without recarburising in the ladle. Not only was this stated, but if Mr. Monell had referred to Table B. and other tables, he would have seen analyses given in which the phosphorus was removed, and 0.3 and 0.40 C. left in the bath of metal; so that his statement was not only incorrect, but absolutely refuted by the results obtained at Pencoyd.

Turning now to the "Homestead" process, it was found to consist in pouring molten metal on to a mixture of iron ore and limestone previously heated to the point of fusion in a basic

hearth. The metal was said to be taken in two ladles ; the interval between the pouring of the one and the other was not stated, but considering that, according to Mr. Monell's own description, the slag rose in a foam, it was not an unreasonable assumption that the vigorous reaction resulting from the pouring of 20 tons of metal into 11 tons of oxide of iron was allowed to somewhat subside before the second ladleful of metal was poured into the furnace. That being so, what had they but a bath of purified and largely decarburised metal covered with an oxidising slag into which pig iron was then poured ? What was this but carrying out the process described by the author ? It was exactly the same, with the exception that a fixed furnace was used with all the attendant disadvantages ; that oxides had to be charged on the bottom to soften it and surely cut it away ; that the slag had to be flowed off through a notch over the fore-plate, and that 40 tons of metal had to be tapped every eight hours instead of 10, 15, or 20 tons at short intervals, as required when working the continuous process in a tilting furnace. As every practical man knew, the semi-melting of large quantities of oxide on the hearth of a basic furnace must inevitably lead to a rapid destruction of the hearth, and in fact was not practicable for continuous work, and the difficulty of removing many tons of slag through a slag notch in fixed furnaces was a most serious matter.

Another point claimed by Mr. Monell as a discovery was that, by keeping the temperature low, he was able to dephosphorise before he decarburised ; but this he, the author, had explained to him when the continuous process was investigated by himself at Pencoyd as one of the experts sent by the Carnegie Steel Co., and it also was specially pointed out by the author in the paper, that by reducing the temperature of the bath the phosphorus was removed before the carbon. That had been well known to metallurgists since 1876, when Sir Lowthian Bell proved it in his washing process.

The analyses of slag given by Mr. Monell was most extraordinary, as it was said to contain 20 per cent. silica, 20 to 25 per cent. iron, phosphoric acid 3·5, and lime 20 to 25 per cent., which left 29 per cent. unaccounted for. Should that gap be filled by oxide of iron ? If so, it somewhat accounted for his

low yield. As the percentage of silicon and phosphorus in the pig iron used were about the same, and the iron ore contained only 3·0 per cent. of silica, one would have expected to have found roughly about twice as much silica as phosphoric acid in the resultant slag, or at most the silica would not have been more than three times the phosphoric acid, whereas it was six times as much. The author's slags when working with pig iron of practically the same phosphorus content contain 7 to 9 per cent. Was Mr. Monell sure that there was not a mistake about the percentage of phosphorus in his pig metal? as if it had been 0·15 or 0·18 instead of 0·5 and 0·8, that would explain both the readiness with which he dephosphorised and the small percentage of phosphoric acid in his slag. To sum up: Mr. Monell had described a process which was old, except in points where it followed the author's process. It had been tried and found unsatisfactory, and in so far as it was a success, was a copy of the work Mr. Monell saw at Pencoyd. By the author's continuous method of working, he not only did everything that Mr. Monell did, but at less cost, with better yield, and in a more workman-like manner.

The remark made by Mr. Riley that he had found that when using fluid metal it had had very little cutting action on the hearth was important. This action of the furnace metal might possibly have been overstated by previous experimenters, but the general experience had certainly been that this had been one of the serious drawbacks to the use of fluid furnace metal in the acid Siemens process. The remarks in his paper had applied, however, more especially to basic practice, where it was customary to use oxides of iron on the bottom of the furnace, by which the basic bottom became impregnated with oxide, rendered more or less soft and fusible, and easily cut away when furnace metal was run into the furnace.

CORRESPONDENCE.

Mr. H. H. CAMPBELL (of Steelton, Pennsylvania) sent the following contribution :—

The use of melted iron upon a basic hearth is nothing new in metallurgy, but with a stationary furnace there are certain difficulties which, though not insuperable, are troublesome. In 1889 I had designed, built, and put in successful operation the first modern tilting furnaces. These furnaces have been running ever since without any change in their construction. In building a new plant, larger furnaces were put up, but the general construction is the same. This style of furnace was described in a paper presented to the Institute by Mr. A. P. Head in May 1899. The centre of rotation of this furnace is the centre of the port, so that the flame can be kept on the furnace during the time the steel is poured out and while the bottom is made. Some years afterwards a modification of this furnace was patented by Mr. Wellman, and is now used at Pencoyd and elsewhere; the main difference is that the flame cannot be kept on the furnace when it is tipped.

In 1891 and 1892 metal was taken from the blast-furnace and put into one of the basic tilting furnaces. The results were very satisfactory, and no difficulties were encountered. It was impossible to continue, however, as the construction of a new open-hearth plant blocked the path of the iron ladles. Owing to certain commercial conditions, melted iron was not available until 1897, when this line of work was resumed, and has been continued more or less regularly ever since. Unfortunately, sufficient blast-furnace metal has not been available to run the entire plant, but the pig iron is used as fast as made, being put into whichever furnace is ready for it. Thus a furnace may run several consecutive heats of fluid metal and then be charged with cold metal. The supply of melted iron is not sufficient to supply even three furnaces out of five basic furnaces of fifty tons capacity, so that the other two are run on cold pig iron with some scrap.

It also happens that the blast-furnace hearth will only hold about 75,000 to 80,000 pounds, while each open-hearth furnace

holds 100,000 pounds. Consequently, it is our practice to charge sufficient cold pig or scrap to make up the full charge. For these reasons it comes about that the monthly records of the department as a whole for the last three or four years show that the proportion of pig iron ranged from 65 to 93 per cent, and the proportion of fluid iron from 50 to 69 per cent. On two of the furnaces, however, during the last three years the proportion of pig iron has been at least 95 per cent., and the percentage of melted iron about 80 per cent. Complete charges of melted iron would have been used if the metal had been available.

It is the practice to charge the ore and the basic additions first. Sometimes these partially fuse, but no advantage has been found in this. When the pig iron is poured into the furnace the temperature is always low, as the melted metal can never be obtained at a steel-melting temperature. It is quite certain, therefore, that the low temperature reactions occur which are characteristic of the pig-washers of many years ago. These reactions were thoroughly investigated by a former generation and placed on scientific record. The removal of the slag first formed is an old idea, and there is more than one way of doing it. Several years ago I published a method of pouring the whole charge from a tilting furnace, and pouring back the steel only, retaining the slag in the ladle.*

Thousands of tons of steel have been made in this way at Steelton. The fluid metal from the blast-furnace is poured into the open-hearth basic furnace, where it is desiliconised, dephosphorised, desulphurised, and somewhat decarburised, and then the whole charge is poured out and the metal alone is tapped from the ladle into another furnace, this other furnace usually having an acid lining. Sometimes only a portion of the charge is taken, and sometimes the whole.

Under ordinary conditions and for ordinary results, we have found that the slag can be run off the furnace through a hole in the bottom of the port, as this place keeps hot and the slag does not chill. This hole is at the joint between the port and the furnace proper.

Owing to the conditions before explained, the records have

* See "Structural Steel," pp. 130, 151 *et al.*

not been kept separate for the practice with melted iron and with cold iron, but under the average use of 80 per cent. pig iron and 50 per cent. fluid metal the output has been 102.9 per cent. With good pig iron the time in the furnace has been as low as $4\frac{1}{2}$ hours, but usually is about eight hours for a 50-ton charge.

It often happens in running a tilting furnace that metal is left in the furnace. This does no harm, and during one week in particular, owing to the contour of the hearth, from 20,000 to 30,000 pounds of steel were left in the furnace after every charge. No attention was paid to this fact, but the ore and lime and melted metal were charged on top of it after every pour, just as if it had not been there.

The foregoing statements give a general idea of what has been done at the Pennsylvania Steelworks for the last few years. It is not considered that any wonderful discoveries have been made, but it seems a proper time to put certain facts on record.

Mr. PERCY C. GILCHRIST (Vice-President) wrote to say that the author ought to be congratulated on having actually obtained 106 tons of steel from 100 tons of pig charged. He made it clear that a pig iron containing more impurities would yield an equally good steel with an even better yield. The method by which the heat necessary for the rapid reaction that took place in his process was obtained was both novel and simple; it was an exceedingly simple plan of stocking heat until it was required. It was probably applicable to furnaces of smaller and larger size, both with or without a movable hearth, as there were no insuperable difficulties in having more than one taphole for either slag or metal. Considering how important Mr. Talbot had proved the question of high heat to be, would it not be practicable to add the basic additions, both white-hot and intimately mixed? The cupola or small blast-furnace described by the Ritter von Schwarz would probably be a suitable furnace for making the additions white-hot. Bearing on that point, it must be remembered that when making the early basic experiments the basic additions that gave the best results were lumps of intimately mixed limestone and oxide of iron; such a mixture, if added while hot, must

melt more quickly than the lumps of lime and oxide of iron that were thrown in separately. When one examined both Mr. Talbot's results and also those obtained by Messrs. Bertrand and Thiel, it seemed clear that not only could ordinary Middlesbrough No. 3 and 4 pig be used by either of those processes to make first-class steel, but that such pig, if taken molten from the blast-furnaces, would for every 100 tons used give at least 110 tons of good steel ingots.

Mr. H. LE NEVE FOSTER sent the following communication :—

The direct process for the manufacture of iron has been the ideal of inventors, and the late Sir William Siemens experimented with this idea for many years, and successfully made wrought iron direct from the ore, but unfortunately this process proved a commercial failure. It seems to me that Mr. Talbot has partially solved this problem, and the success of his process depends chiefly on the direct metal he is able to obtain by the reduction of metallic oxides in his bath by means of silicon, carbon, and phosphorus in his pig, and by this means he has been able to obtain a yield equal to 106 tons of steel for every 100 tons of pig charged.

This extra 10 or 20 per cent. of yield is obtained from the cheapest possible source available, namely, oxide of iron, and at the same time he has utilised the metalloids in the pig as acting reducing agents, whereas in the Bessemer process the metalloids are simply used to obtain the necessary heat to keep the metal in a molten condition.

Mr. Talbot's paper is not only theoretical, but also one of the most practical papers, all the details having been so carefully dealt with. His process combines the advantages of the Bessemer process with the Siemens process, namely, a continuous supply of hot ingots, which to the mill-manager means larger output; larger output means reduction of cost of manufacture and equality of metal produced, as in working a large furnace the metals must of necessity become more uniform in quality, more especially when molten pig is obtained from two or three blast-furnaces, and this is proved by ordinary pig metal mixers.

I should like to ask Mr. Talbot if he has worked pig iron containing 3 per cent. phosphorus; if so, with what results? Does he obtain a higher yield, and what would be the composition of the slag?

I may also point out that there are large deposits of iron ore which at the present time find no market, namely, those iron ores which contain too high a percentage of phosphorus for hæmatite and too small a percentage of phosphorus for basic pig, ores containing from 0.2 to 0.5 per cent. of phosphoric acid. Iron made from this class of ore would seem most suitable for Mr. Talbot's process.

Professor HENRY M. HOWE (Columbia University) sent the following communication:—

It may not be amiss to accentuate a few salient points connected with this very promising process.

(1.) It gives not only a practicable but a convenient way of delivering steel, even from very large furnaces, in small manageable lots.

(2.) What may be called the melting-down troubles arise only once a week instead of with every charge. By these I mean—

(a) The low temperature and the conditions of exposure during melting favour the oxidation of iron and silicon, with the formation of a temporarily siliceous and ferruginous and hence very corrosive slag.

(b) At this very time the bottom is most vulnerable, because it has not yet become covered with a coating of molten metal to protect it from corrosion by this slag.

(c) At the low temperature which exists during and shortly after melting decarburisation must be slow. It cannot be rapid until the temperature has risen much, *i.e.* until after considerable time.

These troubles do not arise in the continuous process (except during the initial melting of each week), for the residual bath of molten metal into which each fresh charge is poured protects the iron of that charge from excessive oxidation; dilutes at once the silica formed by the oxidation of its silicon, so that the temporary stage of siliceous and ferruginous slag is avoided;

protects the bottom wholly from the mild attack even of the calcareous slag present, and quickly raises the temperature so high that decarburisation is rapid.

Why, in view of this latter point, is not the output greater? It is only about seven furnacefuls a week, or about that of common pig and ore practice. Before tapping we must *adjust*; we must bring temperature and composition simultaneously to the right point. This may take time; we may miss, and have to pig back. In common intermittent practice we adjust once for each furnaceful. Mr. Talbot, tapping only one-fourth of his furnaceful each time, makes four of these adjustments per furnaceful. Hence the delay.

It may well be found that the great advantages which his process promises may be combined with the enormous rapidity of the Bertrand-Thiel, which it lacks, by operating both of the Bertrand-Thiel furnaces on his continuous plan.

Mr. ARTHUR WINDSOR RICHARDS (Middlesbrough) sent the following communication:—

In the discussion that followed the reading of the papers by Messrs. Riley and Talbot it was suggested by Mr. David Evans that I should give a *résumé* of the experiments on the duplex process conducted at the works of Messrs. Bolckow, Vaughan and Company, Limited, and I now have pleasure in giving the following particulars.

From a mixer of 120 tons capacity, 13 tons of hæmatite iron were taken and poured into an acid-lined converter, the analysis of the iron averaging:—

	Per Cent.
Silicon	2·5
Manganese	0·50
Carbon	3·5
Sulphur	0·04
Phosphorus	0·06

We desiliconised and partly decarbonised this metal, and then poured it into a ladle resting on a carriage on the ordinary floor level; this was pushed under an overhead crane which travels right over the pits, the ladle was slung in a four-leg chain and

lifted out of the carriage and deposited in a second carriage on a temporary gantry we had erected at the level of the open-hearth charging platform; it was then conveyed by a locomotive to the front of an acid-lined furnace and tilted, the metal running into the furnace by means of a short runner. This whole operation was repeated, as the furnace was of a 25-ton capacity.

To prevent the desiliconised metal from cutting the bottom of the furnace, we always charged a quantity of the slag from a previous charge, and this slag also was useful and necessary to form a coating to the iron to prevent too rapid oxidation, and so forming a thin "cutting" slag. After the furnace had received its second ladle, we took a sample of the bath to examine by fracture, to get an approximate idea of the carbon content we had to deal with, and then added ore accordingly, working the bath down in the ordinary way to dead-soft steel, carbon 0.10. A very few minutes after the second ladle went in the bath was boiling, and, in fact, the first ladleful was often boiling before the second one arrived. On an average we tapped the furnace three hours after charging, though we had some heats out in $1\frac{1}{4}$ hours and others in 6 hours, it all depending on how far we blew the metal; and this I would mention was in a very slow-working furnace, that only obtained nine charges per week on ordinary hand-charging. It took us about 45 minutes from the time we took the iron from the mixer to teeming it into the furnace, so that $1\frac{1}{2}$ hours were occupied in charging. We could obtain 24 to 28 charges per week despite the many delays incidental to an experimental plant.

It was remarkable that the more we blew the iron the less was the wear upon the bottom, and the furnacemen observed that when they obtained well-blown iron they did not use a rabble on the bottom the whole week, and also used very little sand on the banks; while, on the other hand, when we tried using the iron direct from the mixer without blowing and without the use of scrap, the bottom suffered severely. This I account for by the bath taking longer than an ordinary hand-charged one to work, and the boil being so long.

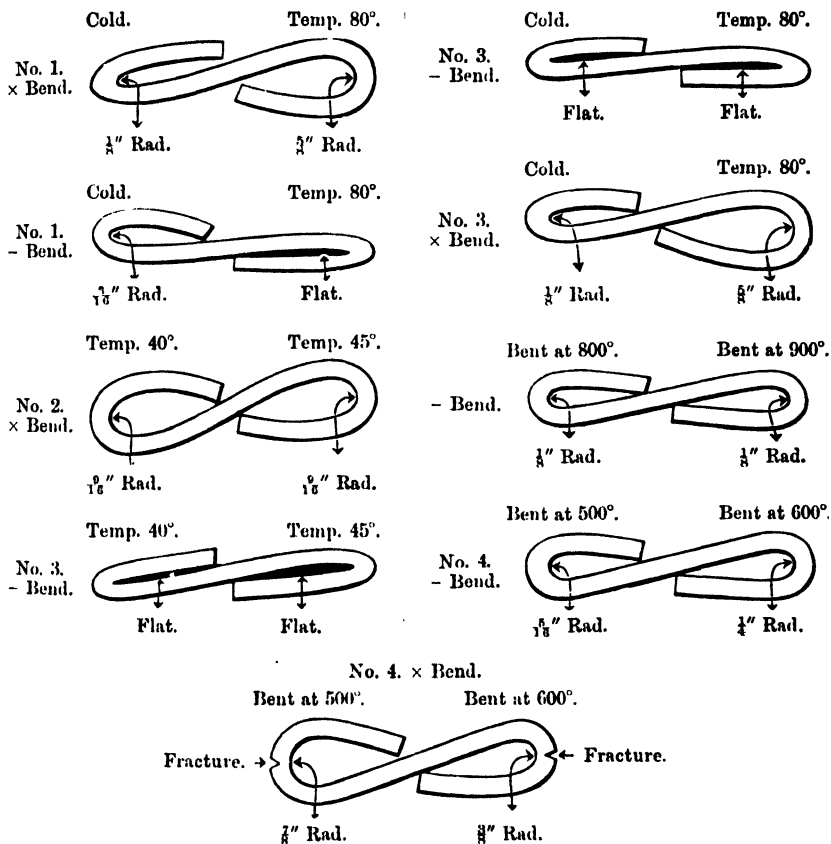
As Mr. Evans pointed out at the meeting, the transit from the converter to the furnace was very slow, and this is where

the yield was affected, as the ladles often skulled for want of quick dispatch. Where the ladles did not skull, the loss from the mixer to ingot was about 9 per cent., which I account for as follows:—In blowing, as we know, the first chemical reaction to occur is the formation of a magnetic oxide of iron at the tuyeres, which arises through the iron desiliconising it and also partly passing into the slag, and from observation I calculate about 1 per cent. of iron is lost to oxidise 1 per cent. of silicon; so that starting with 2·5 per cent. silicon, we have a loss of 5 per cent., the remaining 4 per cent. loss going in the oxidation of the carbon and a slight loss in the furnace, though this is practically nil through charging the slag mentioned and using some iron ore. As compensation against this loss, and also the cost of the blowing plant, three times the output is obtained, the consumption of fuel is consequently reduced 66 per cent., and the maintenance of the furnace is reduced in an even greater proportion, as the output is increased so greatly, and there is less wear and tear owing to the furnace being kept at a uniform temperature. Bearing these facts in mind, and with proper facilities for working, which chiefly means quick transit from the converter to the furnace, I am of opinion this process has yet a future before it, more especially for making a high-grade steel from our native phosphoric ores. The siliceous Cleveland iron could be desiliconised in an acid-lined converter, and afterwards decarburised and dephosphorised in a basic open-hearth furnace.

The following tests, which are typical of the many made, show that the steel produced was of a remarkably good quality, wonderfully uniform and tough, the elongation running up as high as 36 per cent. in 8 inches, and the testing was most carefully made by the representatives of the Admiralty, Lloyds, and ourselves:—

Description.	Cust. No.	Sample No.	Dimensions of Test-Piece.		Ultimate Stress.		Extension per Cent. in 8 Ins.	Bending Tests.		Contraction of Area.	
			Thick-ness.	Width.	Total Tons.	Sq. In. Tons.		Cold.	Temper.	Thick-ness.	Area.	Per Cent.
Tested by Mr. Williams, Lloyds' Surveyor.	J140	-	71	148	29.8	28.3	29	Good.	Good.	...	...
	"	x	7	"	29.3	28.2	25	"	"	...	...
	"	-	8	"	33.3	28.1	31	"	"	...	...
	"	x	8	"	33.5	28.25	30	"	"	...	...
					Temper bend - grain bent nearly flat		}	Rough edges.		}	...
				Cold bend		"					
					Cold bend x grain bent thus		}	Prepared edges.		}	...
					Cold bend x grain bent thus			Rough edges.			
Tested by Admiralty Overseer.	J132	1	57	146	21.5	25.8	31	Good.	Good.	1.0	320
	"	x	58.5	"	22.4	26.2	23	"	"	1.1	440
	"	3	57	"	22.4	26.35	31	"	"	...	...
	"	x	58.5	"	23.1	27.0	26	"	"	...	...
	"	5	59.2	"	23.2	26.8	36	"	"	1.05	383
	"	x	59.2	"	22.9	26.5	25	"	"	1.13	485
Tested by Messrs. Bolckow, Vaughan & Co., Limited.	"	2	58	147	22.0	25.8	26	"	"	Tempered in oil. Weld test.	
	"	4	58.5	146	21.6	25.3	17.5	"	"		
					The tests Nos. 1, 2, 3, 4 were taken from each corner of a plate, and No. 5 from the middle of the plate.						
	J139	1	24	147	10.8	30.6	21	Good.	Good.	...	...
	"	x	24	"	11.2	31.7	20	"	"	...	...
	"	2	37	"	15.8	29.1	23	"	"	...	...
Tested by Messrs. Bolckow, Vaughan & Co., Limited.	"	x	36.5	"	15.4	28.7	22	"	"	...	...
	"	4	44	"	19.0	29.3	25	"	"	...	...
	"	x	45	"	19.8	29.9	24	"	"	...	...
	J133	1	97	"	1.425	40.6	30	"	"	...	...
	"	x	97	"	1.425	40.6	28.5	"	"	...	...
	"	2	73	"	31.6	29.5	30	"	"	...	...
"	x	73	"	32.0	29.8	29	"	"	...	...

The following tests were made by Mr. J. D. James, Admiralty Overseer for the Middlesbrough district, who particularly pointed out bends marked Nos. 4 in sketch, which were made at the critical temperatures 500° and 600°, at which it is very difficult to get steel to bend at all without breaking, and he could not



find anything in the records of the late Mr. John Barnaby, who had investigated this matter very closely for the Admiralty, to equal this steel. It will be noticed that the — grain bent to $\frac{5}{16}$ inch radius at 500°, and to $\frac{1}{4}$ inch radius at 600° without fracture, and the × grain piece to $\frac{7}{8}$ inch radius at 500°, and to $\frac{3}{8}$ inch radius at 600° before showing signs of fracture.

Punching.—A piece of plate 12 inches square was pierced with

$\frac{3}{4}$ inch holes, $1\frac{1}{2}$ inch pitch, drilled through middle, then bent cold across the holes to 90° with slight fracture.

A similar piece with punched holes slightly fractured when bent to 60° .

A row of $\frac{3}{4}$ inch holes, $\frac{7}{8}$ inch centres, were punched along the edge of a plate without bursting.

Drift Tests.—A piece of plate 3 inches wide with a $\frac{3}{4}$ inch hole drilled in it was drifted cold to $1\frac{1}{8}$ inch without any sign of fracture, and a piece 2 inches wide with a drilled $\frac{7}{8}$ inch hole in it admitted of being enlarged to 2 inches diameter before giving out.

Torsion Test.—A sample 10 inches long and $1\frac{1}{2}$ inch wide took two complete turns without fracture.

With regard to the Talbot process, I have followed it with a great deal of interest, and feel quite satisfied that a step has been taken in the right direction. It will appeal more particularly to manufacturers of open-hearth steel who find difficulty in obtaining scrap, but can obtain molten iron low in silicon and sulphur without resort to metal cupolas, as the loss of metallic iron in cupolas is seldom under 5 per cent., which would have to be put against the yield of ingots. One of the most striking points of his paper is the duration of the furnace bottom. When I was at Pencoyd two years ago, Mr. Talbot told me he was bringing out his process, and I immediately questioned whether the bottom would last a week without repairs. I therefore asked him for an analysis of the dolomite he was using, which was as follows:—

	Per Cent.
Carbonate of lime	53.59
Carbonate of magnesia	45.76
Silica	0.22
Iron and alumina	1.00

100.57

This is a very refractory stone indeed, besides which it was of a very good mechanical condition, and this will account in a great measure for his results.

We can handle receivers of molten iron holding 250 to 300 tons each with perfect ease and confidence, and without repairs for months together; and if it were not for the haunting fear of what would happen should a similar receiver of molten steel break away, I cannot see that any serious objection could be

brought against the Talbot process, with its great output and splendid yield.

MR. A. E. TUCKER sent the following communication:—

The process detailed by Mr. Talbot marks an epoch in the history of steel-making, and its beauty will appeal to metallurgists and practical men. The tilting furnace is the mechanical equivalent to the Bessemer converter, in which, however, the blast of air is replaced by fixed oxides. The process becomes, therefore, a direct one to an exceptional degree. Such replacement of blast by ore is manifestly attended with great economy, for in the reduction of the metalloids their equivalent of metallic iron will pass into the bath, and so, with the very large margin of heat secured by Mr. Talbot, the practical yield will more closely approach the theoretical than has hitherto been possible in any pig-ore process, while with pig-scrap, Siemens, or the Bessemer process we have large available sources of heat which are at present largely wasted. The process advocated somewhat vaguely by Mr. Monell shows little or no novelty, and is certainly vastly inferior to that of Mr. Talbot. In the case of the Homestead furnace, the exposure of the hearth to mechanical and chemical wear is alone sufficient to put their process out of court in comparison, while their yield is admittedly inferior. It is difficult to see how the hearth in Mr. Talbot's furnace can possibly be injured even after many months' use, it being uniformly covered with practically inert metal, which secures it from any serious chemical action or mechanical abrasion. The advantage of very practically combining a mixer with a Siemens furnace, by simply making the latter large enough, and thus allowing the blast-furnace manager to send almost any kind of iron along which he may be making, is an economical consideration which should appeal powerfully to Mr. Monell.

Further, Mr. Talbot very properly claims a point in avoiding the cost and delay in charging cold material—*i.e.* no separate time is given them for heating "up to the verge of fusion" before running in the molten pig, as in the Homestead system. Seeing that the interaction of molten metal and oxide, under the conditions described by Mr. Talbot, is most vigorous, the time occupied in raising such additions up to the verge of fusion

(given as ninety minutes) is time largely wasted. Mr. Harbord has shown, in his paper of 1886, that the elimination of silicon, phosphorus, and manganese is very rapid, and it is certain from his experiments, with which I had the pleasure of assisting, that efficiency gained by Mr. Talbot must be lost in the system advocated by Mr. Monell.

In respect to the important question of the richness in phosphorus of the slag produced by the Talbot process, Mr. Harbord pointed out in the same paper that when oxide of iron is used the amount of lime ordinarily added may be reduced. This is a point of much importance in such works as produce valuable manure slag, because with the concentration of phosphorus in such slag we have a much more saleable article. It is to be expected in the near future that such slags as are at present made will in like amount cease to be producible by present processes. The stores of tap and high phosphoric ores appear to be rapidly running out. Hence the fixing of the available phosphorus in a small initial quantity of slag will become, with the increased output of such slag by the Talbot process, a feature of great commercial value. The contention is raised that with the Talbot process dead-soft steel can alone be produced; but from a cursory comparison of the system advocated by the Homestead Company, it is clear that what is with them possible in the production of higher carbon steel is also possible with the Talbot process, no essential difference occurring in the chemical reactions involved. In each the percentage of carbon remaining in the bath will depend on the period of tapping. The silicon, phosphorus, and manganese will, with low phosphorus pig, certainly always be very low when the carbon is anything under 0.35 per cent. As regards the use of scrap in the blast-furnace instead of in the Siemens furnace, I may say that at a works with which I was connected we put some thousands of tons through a blast-furnace, and after making a slight increase in the coke for melting it, we found it a most satisfactory and economical cupola, not the slightest difficulty being met with.

Summarising: In my opinion the Talbot process is quite unique in its efficiency, and I may be allowed to add that the method advocated by the Homestead Works appears to be a poor copy of it, without any practical advantage.

Mr. T. TWYNAM considered that Mr. Talbot had earned the gratitude of the steel industry of the whole world for having pointed out, and proved by actual commercial working, a practical means of bringing about the oft-discussed reactions between the metalloids of molten pig iron and iron oxides. His own experiences when trying to get the benefit of these reactions to any considerable extent in the ordinary basic open-hearth process were certainly not encouraging, owing to the great wear on the furnace bottom. It was interesting to calculate how near Mr. Talbot had arrived at the theoretical possible yield. This could be arrived at from the analysis of the pig iron given and from the results given in Table C. It was to be noted that the theoretical yield varied with the state of oxidation of the iron oxide employed, and that variation assumed quite a considerable amount in favour of an oxide consisting wholly of ferrous oxide, assuming such an ore to be practically obtainable. Thus, to fully oxidise the carbon, silicon, and phosphorus from 100 parts of pig iron of the composition given by Mr. Talbot as being used at Pencoyd, by means of ferrous oxide entirely, would result in the reduction of 2.55 parts of iron, which, added to the 93.8 parts of metallic iron in the 100 parts of pig, would give rise to the formation of 119.3 parts of steel. In a similar manner 100 parts of pig iron, wholly oxidised by ferric oxide, would result in the formation of 110.8 parts of steel. Assuming the purification of the charges given by Mr. Talbot, Sheet 1, Table C., to have been brought about solely by the aid of ferric oxide, and that the carbon passed off as carbonic oxide only, the yield theoretically possible would appear to be 110.3 parts of steel per 100 of metal charged, against an actual yield of 105.4 parts. As, however, the iron oxide employed was largely in the ferrous state, the actual yield would vary still more from the theoretical than the above figures show.

Mr. B. TALBOT, in reply to the correspondence, pointed out that Mr. Tucker's remarks required no comment, as he was practically in agreement with the author on all points.

The results obtained by Mr. Arthur Windsor Richards were most interesting, and there could be no question as to the quality of material produced by the duplex process, and certainly the

tests given by Mr. Richards most strongly confirmed this. The loss of 9 per cent. from mixer metal to ingot was somewhat smaller than one would have anticipated, as taking loss due to silicon as 5 per cent. and carbon 3·5 per cent., it only allowed 5 per cent. for mechanical and other losses. It was probable that some oxide of iron might be reduced in the Siemens furnace, but as no silicon and little carbon was available for this, having been previously removed in the Bessemer, it could not be a large amount, especially when the metal was well blown, conditions which seemed to give the best results in other respects in practical working. Taking, however, 9 per cent. as the average loss, and a gain of 6 per cent. by the continuous process, this difference of 15 per cent. in yield in favour of the latter, especially when taken in conjunction with the cost of maintaining two plants, extra cost in labour, and transferring, &c., &c., would always leave a substantial balance in favour of the direct production in one furnace.

The opinion expressed by Mr. Richards was that the process would more especially apply where a low silicon pig iron was obtainable, but in the author's opinion it was siliceous pig irons which the process was particularly calculated to deal with, as by mere dilution alone whatever silicon was present was reduced to one-third or less if desired to have smaller additions made. It was, of course, admitted that the lower in silicon the more rapidly it was de-siliconised, but within reasonable limits there was not the slightest reason to anticipate trouble from high silicon. With regard to sulphur, it was not suggested that that was more effectively removed than in ordinary basic Siemens practice, but as high silicon pig meant low sulphur in the pig, by the use of a higher silicon pig iron that sulphur difficulty was overcome indirectly when a low silicon and low sulphur pig iron could not be made.

Mr. Gilchrist's suggestion that oxides and lime additions should be fritted together and charged white hot, so that they should be more readily absorbed by the bath, might, under certain conditions of work, be worth consideration, the chief difficulty being to design a furnace which would do this more economically, both as regarded fuel and time, than the open-hearth, when all the difficulties of charging white hot material from one furnace to another were considered.

In reply to the question of Mr. Le Neve Foster respecting 3 per cent. phosphorus pig iron, he had never actually worked a pig iron with this content of phosphorus, because in the States it was practically unobtainable, but he did not anticipate any difficulty, and most certainly he should expect a higher yield. The composition of the slag at the lowest estimate should contain twice the amount of phosphoric acid to that obtained with a pig containing 0·8 per cent. to 0·9 per cent., which gave about 8 per cent. to 9 per cent., so they might reasonably expect a slag with 16 per cent. to 17 per cent. of phosphoric acid.

The point raised by Mr. Foster respecting the utilisation of the large deposits of ores just outside the hæmatite limits was one of the greatest importance, and he anticipated that very great development in that direction might be expected at no very distant period.

In his contribution to the discussion Mr. Campbell commenced by comparing his own furnace with Mr. Wellman's, and claimed that the latter was simply a modification of his own; all that needed to be said with reference to that was, that the modifications were so important, that practically all the leading works in the States which had put down tilting-furnaces had selected Mr. Wellman's modification. Every practical man knew that commercial considerations often prevented, for a time, the carrying into effect of technical improvements which were admittedly desirable; but when it had once been demonstrated that a great saving could be made, commercial considerations did not generally delay matters for nine or ten years, as appeared to be the case with Mr. Campbell. Mr. Campbell told them that the results he obtained with fluid blast-furnace metal were most satisfactory, and no difficulties were encountered in 1891 and 1892; but notwithstanding that, they were discontinued till 1897. Since 1897 he had been using fluid metal only more or less regularly, notwithstanding the fact that some charges had been worked in $4\frac{1}{2}$ hours, and generally had averaged only eight. The reason given was that he had not had a sufficient supply of metal for all his furnaces.

One would have anticipated, with such great advantages as these, that if sufficient metal were not available for all his furnaces, he would have put two or three on direct metal,

and worked them regularly; and one could not help suspecting there must have been some very serious practical drawback to which he had not referred, or he would hardly have allowed such a splendid opportunity of increasing his output to have escaped. Possibly the somewhat irregular "contour" of his hearths, referred to later on, might have deterred him from pushing the use of direct metal to the extent which the excellent results obtained seemed to warrant. Mr. Campbell pointed out that the removal of the slag formed during the early part of the operation was not a new idea, which no one disputed, and in his book, to which he referred, stated that the decanting of the slag even from a tipping furnace was very unsatisfactory. Any one who had seen Mr. Campbell's furnace would fully appreciate that that must be so with his furnace; but with the arrangement for tilting both ways adopted at Pencoyd, it was not only satisfactory, but a practical success. If Mr. Campbell preferred to empty his entire charge into a ladle, and then run the metal again into the furnace, leaving the slag in the ladle, no one wished to raise the slightest objection, but it had no bearing whatever on the continuous process described in the paper, except that it was exactly the reverse method of working. The author's great point was, that he never emptied his furnace except at the week end, but worked on continuously; whereas Mr. Campbell preferred to empty his furnace twice for every heat, and it must be left to practical men to decide which was the better course.

It was then said by Mr. Campbell that it often happened that metal was left in a tilting-furnace, and that for one week, owing to the "contour" of the hearth, he had to leave from 9 to 12 tons in his furnace after tapping each heat. That, in plain English, meant that his hearth was so full of holes that he could not get the metal out, but had to allow it to set in the furnace and charge the next heat on the top. Every practical man knew that both in fixed and tilting furnaces when the furnace hearths got badly cut pools of metal would form in the holes and could not be tapped out, and had to be allowed to set in the furnace. But did Mr. Campbell suggest that because he was able to cite an instance of exceptionally bad practice at his own works that he was carrying out the process as described by the author? With that special form of furnace

when it came to emptying at the end of the week, the "contour" would still necessitate his leaving his 10 tons of metal in the furnace, and it would be interesting to see the results of a fortnight's working under such conditions. The author could only express his surprise that Mr. Campbell should be so proud of this performance that he should describe it for the purpose of giving to the steel world, to use his own words, "a general idea of what they have been doing at the Pennsylvania Steelworks for the last few years."

Some of the advantages the author's process possessed over the ordinary method of work were pointed out very clearly by Professor Howe. When starting the first (filling) heat with fluid metal, as they were doing now at Pencoyd, instead of cold pig iron, even the troubles connected with the melting down of the initial heat disappeared. With regard to adjusting the temperature and composition of the bath, owing to the large reserve of heat stored in the bath, especially when comparatively small percentage additions were made, the temperature varied within a very small range; and by the time the purification was effected in practice, it was found as a rule that there was a good tapping heat. At Pencoyd, where they tap one-third the charge, this variation in heat was much greater than it would be when much larger furnaces were used, and only pig metal equal to one-fifth or one-sixth of the charge were added, and it was in this direction that the author confidently looked for far more rapid work than he had obtained in his first furnace. Professor Howe remarked that the output of the furnace was only about seven furnacefuls; but as a furnace working the author's process held nearly 50 per cent. more metal than a furnace of the same surface area working the ordinary process, owing to the greater depth of the bath of metal, the output of the furnace was increased proportionally. Working the ordinary pig and ore process with a furnace of the same surface area as that at Pencoyd, the output would be, say seven heats of 40 tons each, or 280 tons per week; whereas by the continuous process it was over 500 tons, and from latest returns nearly 600. The author submitted that the correct way to judge of output was the product from a furnace of a given size employing a certain amount of men, irrespective of the amount of metal which the furnace might hold owing to the

depth of the bath. The working of two furnaces continuously, one as a preliminary refinery and the other as a finishing furnace, was a point which had received the careful consideration of the author, and for certain grades of metal such a method of working might possess considerable advantages. It was simply a matter of experiment whether two furnaces working in this way would give a greater output than two working as finishing furnaces, and the author hoped at no distant date to try experiments in that direction. Mr. Twynam's calculation as to how near the author's results approached the theoretical yield obtainable were very interesting, and seemed to show that the theoretical yield was being more nearly approached than Mr. Snelus's remarks would lead one to suppose.

In conclusion, he wished to thank the members of the Institute for the very kind way in which they had received his paper.

The PRESIDENT, in proposing a vote of thanks to Mr. Riley and to Mr. Talbot, said he could only characterise Mr. Talbot's paper as one of the most interesting he had ever heard discussed in that room, and he was sure they would have valuable communications in writing upon it. Then there was one other paper to be read, hardly a less important one, on a subject of the greatest possible interest to them all, by Mr. Adolphe Greiner. He would give them the results of the working of the first blowing-engine that was ever worked by blast-furnace gas.

A BLOWING-ENGINE WORKED BY BLAST-FURNACE GAS.

BY ADOLPHE GREINER, MEMBER OF COUNCIL.

I HAVE to-day the honour to submit to the Iron and Steel Institute a short abstract of the results obtained at the Cockerill Works with the first blowing-engine worked by blast-furnace gas ever employed in any ironworks. It is a great satisfaction to me to be able to point out that this problem, of which I had already described the conditions in a paper read before the Institute in May 1898, has been solved in a remarkable manner by Mr. Delamare-Deboutteville, and by the Société Cockerill's engineers, as I shall be able to show in giving an account of the trials recently made at Seraing on a 600 horse-power engine, which has now been running since the 20th November 1899 with unpurified gas taken from the Seraing blast-furnaces.

Mr. H. Savage gave details at the May meeting of this Institute last year of the principal dimensions of this engine:—

Gas cylinder, diameter	1m. 300 = 4 feet 3 inches.
Air cylinder „	1m. 700 = 5 „ 7 „
Stroke	1m. 400 = 4 „ 7 „
Number of revolutions	80 per minute.
Indicated power	700 horse-power (equivalent to 550 effective horse-power in compressed air delivery at a pressure of from 35 to 40 centimetres of mercury, 6·7 to 7·75 lbs. per square inch).

The photograph (Plate II.) accompanying this notice gives a general view of the engine.

A view (Plate III.) is also given of a 200 horse-power engine used for driving a dynamo, and which has now been at work day and night for about two years.

A series of very precise experiments on the consumption of fuel, the running and useful effect of the blowing-engine, have quite recently been carried out by Mr. Hubert, Professor at the Liège School of Mines, in presence of Mr. Witz of Lille, Mr.

Bryan Donkin (London), Professors Meyer of Göttingen and Dwelshauvers of Liège, and other leading scientific men and ironmasters.

His report, which will shortly be published *in extenso*, will enable me to give a critical appreciation of the results obtained in presence of these gentlemen, and will demonstrate conclusively that not only the programme imposed has been successfully complied with, but that the results obtained have gone considerably beyond it.

On the first day, 20th March, the engine was tested simply as a gas-motor; in view of this the blowing cylinder had been disconnected, and a powerful friction-brake fitted on the outlying length of the main-shaft to absorb the power developed. The power observed was over 600 effective horse-power, and varied considerably during the day, from the lowest limit, being 561 horse-power, to the maximum of 670 horse-power, the mean during the trial having been ascertained at 575 horse-power.

The caloric efficiency of the gas per cubic metre, measured by the calorimetric bomb of Professor Witz, was as follows: Minimum, 965; maximum, 999; mean, 984. Measured by Junker's calorimeter these efficiencies varied between 798 and 937 calories, the mean being 860.

The consumption of gas per effective horse-power was 3156 cubic metres (111·4 cubic feet), and per indicated horse-power 2·56 cubic metres (90·36 cubic feet).*

The second day, 21st March, the brake was taken off the shaft and the engine run as a blowing-engine. By more or less closing the outlet valve, the wind pressure was caused to vary. During three hours in the morning the speed of running was 84 revolutions per minute with a pressure of 40 centimetres of mercury, equal to 7·75 lbs. per square inch. After noon the engine was run three hours at a speed of 94 revolutions, blowing at a pressure of 45 centimetres of mercury, equal to 8·72 lbs. on the square inch. Finally the engine was run at the high-blast pressure of 62 centimetres of mercury, equal to 12 lbs. per square inch, the speed falling to 62 revolutions.

* We repeat here what has already been said, that no further cleaning of the gas is attempted than the usual means in use when the gas is burned in boiler furnaces. There is no special cleansing or purifying process employed.

The quality of the gas appeared to be rather better on the 21st than on the first day.

The mean power developed during the morning was 561 effective horse-power, and during the afternoon 725 horse-power.

The consumption of gas was for the morning trial 3·113 cubic metres (109·88 cubic feet) per effective horse-power, or 2·345 cubic metres (82·77 cubic feet) per indicated horse-power and per hour.

For the afternoon trial the results were 2·863 cubic metres (101 cubic feet) per effective horse-power, 2·333 cubic metres (82·35 cubic feet) per indicated horse-power and per hour.

The caloric efficiency of the gases gave by the Witz method for the morning trials an average of 99 calories, and for the afternoon trials of 1004 calories.*

The thermal efficiency or ratio between the power developed and the mechanical work equivalent to the heat of combustion was equal to 30 per cent. in the trials of the 21st March.

Approximately the heat balance of the engine can be established as follows :—

Heat converted into work in the cylinder	.	.	.	30	} 100
„ carried off by the water-jacket	.	.	.	50	
„ „ by the escaping gas	.	.	.	20	

This efficiency is highly remarkable. It is well known that in a perfect steam-engine the efficiency, taking into account that of the boilers, is never more than 12 per cent.—according to Professor Hubert. In our ordinary blowing-engines the efficiency is much lower, and often falls to one-half of the above figure. This being the case, the experiments justify the opinion I expressed two years ago, that the gas-engine, for equal power only, consumes from one-sixth to one-fifth of the gas which would be required for raising steam for use in an ordinary engine.

It further results from Professor Hubert's experiments that the ratio between the work done in compressing air and that corresponding to the combustion of the gas, according to the figures given by Mr. Witz, is equal to 22 per cent.—a magnificent result.†

On the whole the 600 horse-power engine marks a new ad-

* By Junker's calorimeter these figures were found to be 876 and 888 calories.

† The same ratio, taking as a basis the results obtained with the Junker's calorimeter, is 25 per cent.

vance in the construction of gas-motors. Whereas in 1898 Professor Witz found that the consumption of a 200 horse-power motor of 3.33 cubic metres (117.6 cubic feet) of gas per horse-power and per hour was almost "unhoped for," it is now well ascertained that the consumption of gas similar to that tried in 1898 should be reduced to 3 cubic metres (105.9 cubic feet) and even lower with the 600 horse-power engine.

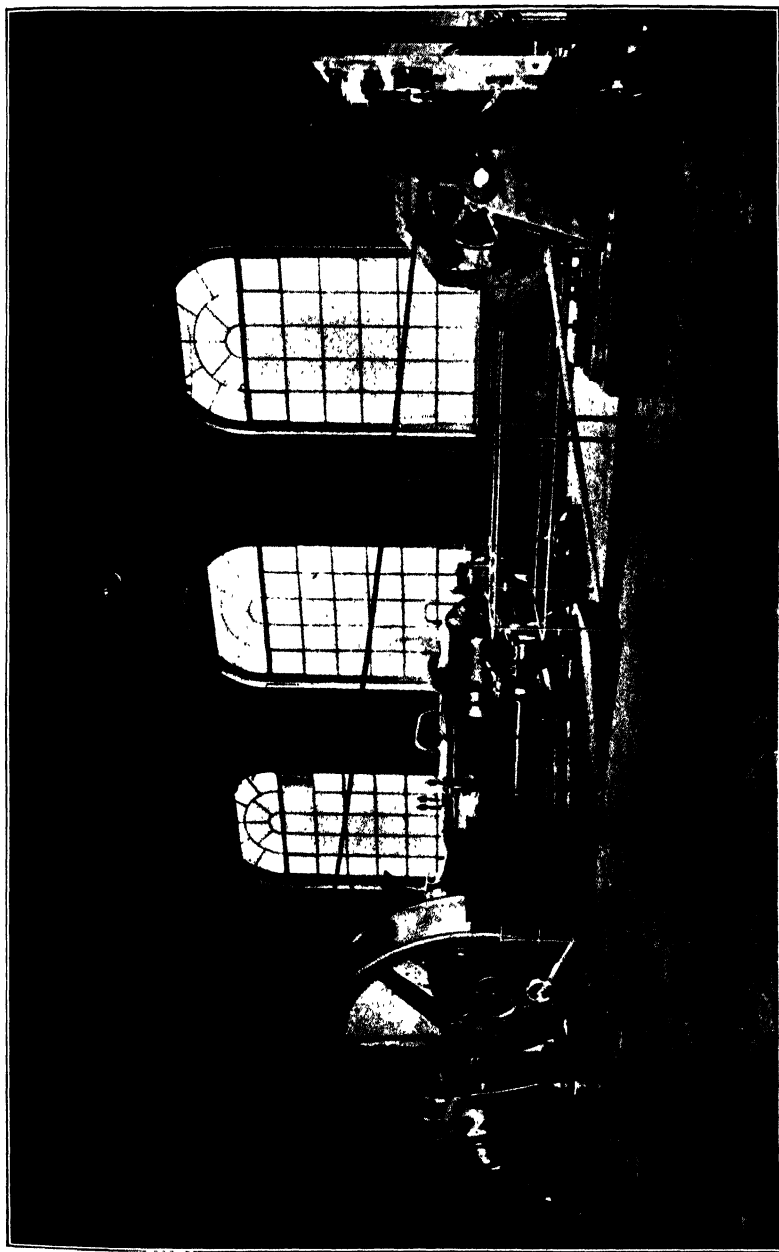
This engine suffices easily for a production of from 150 to 160 tons of pig iron per 24 hours at the Seraing blast-furnaces.

But we have no intention of stopping at 600 horse-power. Drawings are already ready for three 1200 horse-power blowing-engines which have been ordered for a Lorraine works, of which the furnaces make daily 300 tons of pig iron from oolitic iron-stone containing 30 per cent. of iron. The problem to be worked out is as follows: Supply 600 cubic metres (21,180 cubic feet) of air per minute at a normal pressure of 95 centimetres, equal to 19 lbs., and we hope to solve it by the use of two gas cylinders arranged tandem fashion with a diameter of 1m. 40 (55 inches), stroke 1m. 30 (51 inches), and a blowing cylinder of 1m. 85 (73 inches) diameter. As in the 600 horse-power engine, we have been able to develop an air pressure of one and a half times the ordinary working pressure, so in the new engines we expect to be able to blow when necessary at pressures of from 25 to 30 lbs.

These engines will be at work towards the middle of next year, and will be fitted to deal with the American style of working of the blast-furnaces just mentioned.

Finally, it may be of interest to point out to this Institute that amongst the seventy gas-engines of the Delamare-Cockerill type, representing altogether 35,000 horse-power, at present ordered, there are some destined to works which could not have been established if the new invention had not been brought into effect. I may mention the blast-furnaces at Toula, in the neighbourhood of Moscow, in a situation where water is entirely absent, and a still larger works in the island of Elba, under identical circumstances. The furnaces in this island, where fresh water is non-existent, require three 600 horse-power blowing-engines, and three gas-motors for electric plant of 200 horse-power each.

PLATE II.





DISCUSSION.

Dr. LUDWIG MOND said he had very great pleasure in complimenting Mr. Greiner and the Seraing Company on the very great progress they had made in bringing out a large gas-engine. That always looked a very simple problem. Theirs was called the "Simplex" engine, but it was one which in less expert hands did not seem to be very successful in France, and it had to be transported to Belgium to make a success. At the same time he would like to tell the members present that they had not been standing quite still in England during this time, and that he had now had at work for a month at Northwich an engine built by the Crossley Company of 430 horse-power which gave every satisfaction, and that another engine of about 500 horse-power was now going through its trials at the Premier Gas Engine Company's works, and would very shortly, he hoped, be running at Winnington. Both those firms were quite prepared, as he understood, to go up to 1000 horse-power and larger, since they had found there was really no difficulty in building gas-engines of large size.

Mr. WILLIAM HAWDON (Middlesbrough) said he would like to ask Mr. Greiner a question. He understood they had no scavenging in their engines, but did not Mr. Greiner find that the gas left in the space at the back of the piston, which after the explosion was useless, very much interfered with the capacity of the engine? With a scavenging engine they scavenged with air, and that air was used to explode the next charge; but in the Seraing engine they had to mix the already-used gas with the new charge; and if they used a scavenger they could use a very much smaller cylinder than they did with the present arrangement.

Mr. BRYAN DONKIN said he had had the pleasure of being present at the trials, and had great satisfaction in bearing testimony to the careful way the details were attended to. The gross results had been given, but no indicator diagrams, which
1900.—i.

would be published later. The engine worked extremely well. He had been at Seraing, in company with several experts, for two or three days, and was much interested in the subject. There was only one point in the paper that he would like to comment upon, and that was that the calorific value of the gas was given, without saying whether the water in the calorimeter was taken as condensed or not. Again, it was stated that in a steam-engine there was seldom more than 12 per cent. thermal efficiency, taking the boiler and engine together, whereas this gas-engine gave an efficiency (taking the indicated horse-power) of 30 per cent. But it was hardly fair to compare the 30 per cent. of the one heat motor with the 12 per cent. of the other in this way, because in the former case the efficiency of the blast-furnace ought also to be taken into account. From another point of view he thought he was right in saying that the heat efficiency of the gas-engine was 25 per cent. per brake horse-power. Mr. Delamare wished him to mention, in reply to Mr. Hawdon's question about an air scavenging charge, that in the Simplex gas-engine there was none.

Sir LOWTHIAN BELL (Past-President) asked whether the blast from one gas-furnace was used for driving that blast-engine?

Mr. GREINER replied that they were all mixed together.

Mr. HORACE ALLEN had listened with great interest and appreciation to Mr. Greiner's paper. He considered that if a thermodynamic efficiency of 22 per cent. in the work of compressing air by the use of blast-furnace gas could be proved to have been obtained, by reports of unprejudiced competent engineers, that result was remarkable and creditable, and should alone convince ironmasters that the utilisation of blast-furnace gas for power purposes, by combustion in internal combustion engines, was the greatest advance in the metallurgy of iron during the century. In regard to the statement near the end of the paper, it appeared to him to admit of serious qualification, especially in the absence of a more detailed description. If it were desired to utilise the crude or unpurified gas from a blast-furnace in steam-boiler furnaces at a distance of 260 metres away, the tube for

conveying the gas would require to be of such a diameter as to admit of workmen getting inside to clean out the accumulation of dust from time to time; but all ironworks engineers would line the tube with brickwork to reduce the loss of heat by radiation, delivering the gas to the boilers at as high a sensible temperature as possible, a condition altogether undesirable in the case of the application of blast-furnace gas to a gas-engine. Referring to the very indefinite sketch-plan accompanying Mr. Greiner's paper, the primary vessel near the stoves being designated the dry-washer would seem to imply that, and quite foreign to the use of crude or unpurified blast-furnace gas in steam-boilers, water was used in the form of spray, or in some manner which, while removing a portion of the dust, still left the gas in a more or less highly heated condition; otherwise he failed to understand the meaning of the term dry-washer, and the sloping bottom of the vessel shown in the sketch appeared to confirm his assumption. If his surmise was correct, the amount of aqueous vapour in the gas would be increased at this point, which in itself would be a great disadvantage. Assuming that the gas-heaters shown were not put down as in any way connected with the utilisation of the gas in gas-engines, the tube as far as the dust-catchers would in all ironworks be lined, in order to preserve as far as possible all the original sensible heat, with brickwork, but from that point on he would suppose there would in the Seraing application, and for obvious reasons, be only the bare tube, in which case it would act in a slight degree like a specially designed cooler, and the vessel situated near the engine, called a cooler, an apparatus never associated with the use of crude blast-furnace gas in gas-engines, would probably have the effect of further cooling the gas below 100 degrees Cent. (212 degrees Fahr.), in which case the aqueous vapour would, to a considerable degree, depending upon the efficiency of the cooler, be condensed into free water, which in the vessel would more or less separate from the gas and carry down with it a notable proportion of dust, the tube and vessels therefore constituting a sequence of physical purifying apparatus, certainly not unlike the system employed by Messrs. Thwaite & Gardner. Stoppages at intervals would be necessary for the cleaning of the tube, therefore the system could not be considered continuous.

The drawing of the gas-driven blowing-engine, patented by Messrs. Thwaite & Gardner, which he had had the pleasure of showing them, was being applied in an important Midland ironworks. It had two gas motor cylinders, side by side with a single acting blowing cylinder placed vertically over the crank-shaft. The system of valves for the air cylinder, Gordon's patent, was an advance over the usual type used in slow-running engines, being perfectly balanced and noiseless, as well as opening and closing at the exact point required; on the discharge side the valves did not open until the desired compression was almost reached. The adoption of such valves enabled the Thwaite-Gardner engine to be run at twice the speed of Mr. Greiner's blowing-engine, thus delivering twice the volume of air for a given diameter of cylinders.

In Mr. Adolphe Greiner's paper on the use of blast-furnace gas for motive power of May 6, 1898, he gave the calorific value of the gases from the Seraing blast-furnaces, as determined by Mr. Witz, at 0° C. and 760 mm. pressure as 987 calories per cubic metre; but crude or unpurified blast-furnace gas, as it left the furnace, had a physical or sensible temperature about 340° C. (650° F.), and allowing for a fall of temperature between the top of the furnace and the blowing-engine house to 315·5° C. (600° Fahr.), the calorific value of a cubic metre at 315·5° C. and 760 mm. pressure would only be 459 calories. If the crude gas was purified, involving the removal of the sensible heat, so that the temperature was reduced below 100° C. (212° Fahr.), without proper provision for removing the condensed aqueous vapour, the thermal value of the gas for the development of power in the cylinder of a gas-engine would be reduced by the amount of latent heat necessarily required to evaporate the water introduced with the blast-furnace gas. Thus, if the gas was employed at a temperature of 0° C. (32° Fahr.), and it contained 10 per cent. of aqueous vapour, about 9 per cent. of the heat value of the gas would be absorbed in the evaporation of that amount of water.

He would like to ask Mr. Greiner the following questions:—

1. Does Mr. Greiner use the word crude or unpurified blast-furnace gas to represent the condition of such gas in the state in which it is introduced into steam-boiler flues, that is to say, when

the gas has a comparatively high sensible temperature, and contains a high proportion of aqueous vapour and suspended solid matter?

2. Will Mr. Greiner say what is the temperature of the crude gas when it reaches the gas-engine?

3. What is the proportion of aqueous vapour in the gas when it is introduced into the gas-engine?

4. What is the calorific value of crude gas per cubic metre in the condition chemically, physically, and thermally when it first leaves the furnace? and, secondly, when it is introduced into the gas-engine?

5. What is the guaranteed weight of oil used in lubricating the gas motor cylinder and moving parts per effective horse-power day of twenty-four hours, continuous working results?

6. What is the independently determined mechanical efficiency of the engine proved by an automatic volt and ampère meter record, or other suitable unerring method?

7. What is the ratio of the weight of all the moving parts of his blowing-engine to the effective horse-power developed per hour?

8. Reference was made by Mr. Greiner to a 200 horse-power engine working electrical machinery—what does the horse-power mean? Would Mr. Greiner provide an automatic record, in kilowatts developed, of this engine, and say what is the consumption of lubricating oil used per kilowatt year? In the absence of the information that a full and frank reply to the foregoing interrogations will give, there is no reliable basis on which to draw comparisons or estimate the value, if any, of the progress claimed by Mr. Greiner. Supposing the blast-engine were situated near the blast-furnace, would the 260 metres of tubing of $1\frac{1}{2}$ metres diameter still be employed, or would that be unnecessary?

Mr. ADOLPHE GREINER, Member of Council, in reply, said that he wished only to make one or two brief remarks. The first point was that he had put before the Institute in May 1898 a statement forecasting the results referred to in the present paper, and that the opinions then advanced had been fully justified. The first 600 horse-power blowing-engine driven by gas, of the de-

sign shown in the drawings exhibited, was now at work. He felt sure that the possibility of using to the best purpose the enormous quantity of gas which was lost in blast-furnace practice, would compel manufacturers to give their attention to the new idea. He was, moreover, sure of the soundness of the principle enunciated when, two years ago, he stated that a much higher useful effect could be obtained by the direct use of gas in motors than by the ordinary method of employing them to raise steam in boilers. When he had said that a small blast-furnace making 100 tons of pig iron a day would give off gas enough to drive a 2000 horse-power engine, he had not in any way overstated the case, and he expected future results to fully bear out his calculations in that respect. As every one there knew, 2000 horse-power corresponded to a consumption of two tons of coal per hour, and taking the cost of coal at 10s. a ton, the daily saving amounted to £24, or, reckoning 300 working days in a year, to £7200 yearly. This sum would more than cover the first cost of such an engine as he described, which amounted to about £6000. Taking now the output at 100 tons per diem, the daily saving in fuel—£24—worked out to nearly 5s. per ton of pig iron produced. If the iron were worth, as in the case of Cleveland pig, say 60s. per ton, the saving could be estimated at 8 per cent., or, in the case of hæmatite, at 80s. per ton, 6 per cent. of the whole cost price.

Designs were being considered for a 1200 horse-power engine on order for the Lorraine Works, and four cylinder engines of 2400 horse-power were contemplated, of which in the course of the next two years he hoped to be able to give some account.

A hearty vote of thanks was accorded to Mr. Greiner for his paper, and the proceedings were then adjourned till the following day, Thursday, May 10th, when the following paper was read :—

THE MANUFACTURE AND APPLICATION OF WATER-GAS.

By CARL DELLWIK.

THE utilisation of fuel has always been, and is likely to remain, a subject of the greatest importance to the iron and steel industries; perhaps even more so than to any other branch of manufacturing. Any improvement in the application of heat, be it as a matter of economy of fuel, or a saving of time, or an attainment of superior results in any other manner, will therefore be of interest to manufacturers. It is for this reason that I venture to bring to your attention a subject which, though it touches only indirectly on the manufacture proper of iron and steel, yet is apt to have an important bearing on the manipulation of these materials.

Water-gas as such has long been known, and its merits have on a previous occasion been discussed at length before this society. Later experience and its failure to come into general use have seemed to bear out the unfavourable criticism then made against it. But in the last few years the water-gas industry has entered into a new line of development, which has opened up possibilities which formerly could not reasonably be expected.

When water-gas was first introduced a number of years ago, it was manufactured by a process which transferred into the gas only about one-third of the heating value of the fuel. It could, therefore, not compete in price with other methods of heating in any cases where by other means a good utilisation of the fuel could be effected. It was, in fact, predestined for use only for such special purposes, where the practical advantages it offers could ensure an efficiency in the application which would counterbalance the wastefulness of its production. Nevertheless attempts were made to apply water-gas in competition with other methods of heating already giving favourable results. In many cases such attempts led to technical success and economical failure,

and the latter, often leaving the more lasting impression, has caused water-gas to be looked upon with a considerable degree of prejudice and disfavour, which even at the time it did not altogether deserve.

Of late years these conditions have been subject to a very marked change, and it has been amply demonstrated that it is practically possible to produce water-gas by means of a simple and easily handled apparatus, with a degree of economy which not only rivals, but surpasses that of other methods now in general use for the production of a much less valuable gas.

In this connection it should not be overlooked that for some years past water-gas, enriched with oil-gas, has become an important factor in the English gas industry as auxiliary to coal-gas works, but this has, of course, had no direct bearing on the application of water-gas for industrial purposes, and does not here come into consideration.

My present object is to explain the theory on which the Dellwik-Fleischer process is based and the results obtained in practice, as well as to give a short account of some of the applications which have been made for manufacturing purposes.

The value of a gas for industrial purposes depends mainly on two considerations, viz. :—

- (1.) Its adaptability for each specific purpose ; and
- (2.) Its price as compared to other fuels capable of being used, though perhaps less advantageous from a purely technical point of view.

Speaking in general terms, there can be little doubt that the higher the quality of a gas is, the more readily it may be adapted for the great variety of purposes for which gaseous fuel is used in modern manufacturing. So, for instance, ordinary producer-gas, of which 55 to 60 per cent. consists of incombustible elements, is quite useless for certain purposes where coal-gas and water-gas have proved to be excellent sources of heat.

On the other hand, coal-gas, by reason of its high price, the complicated and costly appliances required for its production, and other disadvantages, is practically excluded from use on a large scale for manufacturing purposes. As regards price, the same objection, though in a lesser degree, until recently held good against water-gas, except, as has already been mentioned,

in special cases where the economy of its application was so great as to counterbalance the waste of energy in its production.

For general manufacturing on a large scale, producer or Siemens gas has therefore remained unrivalled as offering the cheapest means of heating large furnaces.

It is, however, evident that, given the possibility of converting fuel with the same degree of economy into a gas of a higher calorific power than producer-gas, such gas cannot fail to obtain a vast sphere of utility.

Water-gas being all combustible, having a very high flame temperature, and per volume more than twice the calorific power of producer-gas, in all respects fulfils the technical requirements as regards quality.

Before proceeding to an account of practical results, I will enter into a short theoretical comparison between producer-gas, water-gas manufactured by what I will call the "old" processes, and water-gas manufactured by the Dellwik-Fleischer process.

When 1 lb. of carbon is burnt to carbon dioxide (CO_2), it develops 8080 thermal units ($^{\circ}\text{Cent.}$); when burnt to carbon monoxide (CO), it gives off only 2400 thermal units. As the Siemens process consists in burning the carbon to carbon monoxide, it follows that the gas produced from 1 lb. of carbon contains $8080 - 2400 = 5680$ thermal units ($^{\circ}\text{Cent.}$), corresponding to a utilisation of about 70 per cent. of the heating value of the solid carbon. This figure, therefore, roughly represents the maximum theoretically possible utilisation in the cooled gas of the heating value of the fuel, when losses from radiation and other sources are not taken into account.

The process of water-gas manufacture consists in the alternate heating of a bed of fuel to incandescence by means of an air-blast, and the subsequent decomposition of steam in contact with the fuel thus heated, until the decrease in temperature necessitates a new period of heating.

In all processes hitherto in use, both of these periods (of water-gas making and of blowing) have yielded combustible products, each containing a portion of the heating value of the fuel. The generators may have varied in form, using an air blast, or a forced draft, or a down draft for the periods of heating or blows, but the chemical reaction has always been the same,

viz., a combustion to carbon monoxide, so that the gas leaving the bed of fuel in the generator has consisted principally of carbon monoxide and nitrogen. The most important problem in the construction of a water-gas plant on a large scale on this principle has therefore been to find suitable employment for this producer-gas, which contained the greater portion of the heat of the fuel. The difficulty of doing this, and especially the difficulty of utilising it in the same proportion as it was generated, has, in fact, formed one of the most serious obstacles against the introduction of water-gas. Various devices have been resorted to for the purpose of utilising the producer-gas for increasing the yield of the more valuable product, water-gas, such as preheating of the air or steam, or both, for the water-gas generator. All such arrangements have, however, proved more or less ineffective, besides complicating the apparatus, and the ordinary practice in the production of "blue" water-gas has therefore been simply to use the producer-gas to generate the steam for the water-gas manufacture. But even this has by no means always been done, and the insufficient utilisation of the fuel has been such as to effectually prevent the general introduction of water-gas.

As the chemical reaction in the generation of the water-gas is always the same, it is evident that the condition for an economical production of water-gas is to effect the greatest possible utilisation during the blows of the heat contained in the fuel, and the means to accomplish this is to produce a complete combustion in the generator. Practical results have proved that it is possible by very simple means to establish such conditions in the generator, that during the blows a practically complete combustion to carbon dioxide is obtained within the bed of fuel to be heated, while at the same time conditions favourable to the water-gas making are maintained.

This, then, is the radical difference between the "old" processes and the one which I have devised, that while in the former the gas leaving the generator during the "blow" contains principally carbon *monoxide* in addition to the inevitable nitrogen, in the latter it consists principally of carbon *dioxide* and nitrogen.

Given this difference in principle, we will now proceed to inquire into the effect of these different methods.

If we look at the chemical reaction in the formation of water-gas, we find that 18 lbs. of steam, consisting of 2 lbs. of hydrogen and 16 lbs. of oxygen, require for their decomposition $2 \times 28,780 = 57,560$ thermal units. The 16 lbs. of oxygen combine with 12 lbs. of carbon to 28 lbs. of carbon monoxide, which in mixture with the 2 lbs. of hydrogen form 30 lbs. = 753·4 cubic feet of water-gas. The heat developed by the formation of the carbon monoxide is $12 \times 2400 = 28,800$ thermal units, thus leaving a balance of $57,560 - 28,800 = 28,760$ thermal units, which must be replaced by combustion of carbon during the blows. Assuming, then, as is approximately the case in practice, that the blow-gas leaves the generator at a temperature of 700° C., we find—

	'Old' Methods.	Dellwik Method.
1 lb. of C. requires for combustion .	to CO — $\frac{10}{12}$ lbs. O.	to CO ₂ — $\frac{32}{12}$ lbs. O.
This O. is accompanied by . . .	4·32 lbs. N.	8·64 lbs. N.
And the products of combustion carry with them at 700° C. .	1136 thermal units.	2092 thermal units.
The heat of combustion of 1 lb. C. is .	2400 thermal units.	8080 thermal units.
The balance available for heating the fuel is therefore . . .	$2400 - 1136 = 1264$ thermal units.	$8080 - 2092 = 5988$ thermal units.
To fill the before-mentioned balance of 28,760 thermal units at the production of 30 lbs. of gas, there must then be burnt . . .	$\frac{28,760}{1264} = 22\cdot75$ lbs. C.	$\frac{28\cdot760}{5988} = 4\cdot83$ lbs. C.
Not counting the heat lost by radiation and other causes, there are then required for the production of 30 lbs. = 753 cubic feet of water-gas . . .	$12 + 22\cdot75 = 34\cdot75$ lbs. C. 21·7 cubic feet water-gas.	$12 + 4\cdot83 = 16\cdot83$ lbs. C. 44·7 cubic feet water-gas.
Or per 1 lb. of C. are obtained .		
As water-gas of theoretical composition contains 167 thermal units per cubic foot, there are utilised in the water-gas from 1 lb. of C.	3627 thermal units = $44\cdot8$ per cent. of the heating value of the C.	7465 thermal units = $92\cdot5$ per cent. of the heating value of the C.

The practical working of these three different processes—for Siemens gas and water-gas—is of course somewhat at variance from the theoretical calculations. In all of them there are losses from radiation, &c. ; in all of them there is formed a certain amount of carbon dioxide, which is, however, to some extent compensated for by an equivalent development of hydrogen, which also tends to increase the volume. On the other hand,

there is a gain from dry distillation when bituminous fuel is used. In the Siemens process there is a further gain by the decomposition of steam in the generator at the expense of the heat developed in burning the fuel to carbon monoxide, so that its practical efficiency may be estimated at from 60 to 72 per cent.

In the old water-gas processes the producer-gas formed during the "blows" is amply sufficient for generating the steam needed for the process, though, as before mentioned, it has by no means always been so used. When a combustion to carbon dioxide is effected in the generator, this advantage is of course lost, the waste heat being only sufficient for preheating the feed-water for the boiler. It is therefore necessary, in this case, to add for boiler fuel 12 to 15 per cent. to the fuel used in the generator. This reduces the theoretical quantity of gas obtainable from 12 lbs. of carbon to 656 cubic feet, and the possible utilisation of the heating value of the fuel to about 80 per cent.

The practical working of the Siemens process is too well known to be dwelt on here. The results of the older water-gas processes are also matter of common knowledge, having been frequently reported in technical journals and handbooks. In generators of small size a yield of about 12·5 cubic feet per lb. of coke of ordinary quality may be counted on, while large generators under favourable conditions produce about 16 cubic feet per lb. of coke.

The water-gas obtained in practice is of somewhat different composition from that theoretically calculated, and its calorific power is about 158 thermal units per cubic foot. If the coke averages 7000 thermal units per lb., then the utilisation of the heat by these processes is 28 to 36 per cent.

It then remains to ascertain how nearly the Dellwik-Fleischer process in practice approaches the theoretical computation.

It is now nearly three years ago since the preliminary experiments were completed, and some of the recognised authorities of the gas industry invited to examine into the results obtained. The first to accept such an invitation was Professor Vivian B. Lewes of London. He has summed up the result of his test as follows :—

"One thousand cubic feet of water-gas, containing 15 lbs. of

carbon, are obtained by a total expenditure of 29 lbs. of carbon, so that over 51 per cent. of the carbon is obtained in the gaseous form, while the expenditure of the other 49 per cent. results in the hydrogen of the water-gas.

"The coke used in the experiments made contained 87.56 per cent. of carbon, or 1961.3 lbs. per ton, equal to 15,876,307 thermal units ($^{\circ}$ C.), and this amount yielded 77,241 cubic feet of water-gas. The specific gravity, as taken by the Lux balance, was .5365, and its gross calorific value, as determined in Junker's calorimeter, was 4089 thermal units. Hence the calorific value of the water-gas from a ton of coke was 13,033,059.8 thermal units, or over 82 per cent. of the heating value of the total coke used in both generator and boiler.

"From this calculation 20 per cent. of the coke has been taken as used for raising steam, but in a large installation this figure could be reduced, and the percentage of the total heating value of the coke obtained in the gas slightly raised. The labour needed will be less than with the ordinary process, as less fuel has to be handled."

Other tests made by Professor Bunte of Karlsruhe, Professor Lunge of Zurich, Dr. Leybold of Hamburg, and others, have given similar results. The most trustworthy figures for continued work have been obtained from an installation at the Corporation Gasworks at Königsberg in Prussia, where an average yield of 38.44 to 39.72 cubic feet of water-gas are obtained per lb. of carbon contained in the coke which is charged into the generator. This corresponds to a utilisation of 75.2 to 77.7 per cent. of the calorific value of the fuel. At another gas-plant the tests showed a yield of 41.6 cubic feet per lb. of carbon, or an efficiency of 81.3 per cent.

The method of working the generators illustrates the difference from the old methods. In the latter the duration of the blow was from ten to fifteen minutes, while the water-gas was made during the following four to five minutes. In the Dellwik generators the blow lasts only one and a half to two minutes, while water-gas is subsequently generated for eight to twelve minutes. During the blow the combustion continues throughout the entire depth of the fuel, and the whole bed of fuel is thus raised to an even high temperature, enabling the periods of

water-gas production to be considerably lengthened without any deteriorating effect on the quality of the water-gas.

Plate IV. shows the appearance of a generator. The surrounding sheet-iron shell is lined with firebrick. On a level with the clinkering doors is a grate supporting the fuel; below are ash doors for removal of the ashes. The air enters through the blast-valve, and the blow-gas leaves the generator through the central stack-valve, through which the fuel is also charged by means of a small coke-waggon. There is one water-gas outlet at the top of the generator, and one below the grate, both connected with a three-way valve, through which the gas passes on its way to the scrubber. The gas-pipe is sealed with water in the bottom of the scrubber, where the gas is cooled and all dust washed out by the water running through the coke, with which the scrubber is filled. From the scrubber the gas passes on to a small holder, which equalises the flow of gas to the place of consumption. There is a steam-pipe leading in to the bottom and another to the top of the generator.

The method of working is as follows. A fire having been built on the grate, and the generator filled to the proper level with coke, the blast-valve is opened, and the fuel raised to a high degree of incandescence in a few minutes. Then one of the gas outlets—the upper one, for instance—is opened, the blast and stack valves being simultaneously closed by means of the gearing on the working stage. Steam is then admitted to the bottom of the generator, and, passing up through the bed of incandescent coke, is decomposed, forming water-gas. A set of water-gauges and a test-flame indicate the condition of the apparatus and the quality of the gas. When the temperature of the fuel has sunk below the suitable point, so that carbon dioxide begins to form in a larger proportion, the steam is shut off and the stack valve opened, the gas-valve being simultaneously closed. The blast-valve is then opened for another blow of one and a half to two minutes. For the next period of gasmaking the lower gas outlet is opened and steam admitted above the fuel. By thus reversing the direction of the gas-making, the temperature of the fuel is equalised, causing less wear on the brick-lining at any one point. The greater part of the coke being consumed by the action of the steam, the incom-bustible portions of the coke to a large extent disintegrate and

fall through the grate as ash, while the clinkers on the grate are brittle and easily removed.

From the results which I have already quoted, it is evident that by this process there is no difficulty in obtaining an efficiency rather higher than that usual in the Siemens process, and twice as high as that of the older water-gas processes. It is unnecessary to make any comparison with the latter as to price. But in regard to the former, the thermal efficiency is so nearly equal, that the advantage of using one or the other of the two gases must almost entirely depend on the relative advantages they offer for practical use. The question thus becomes one of quality of the product obtained.

Siemens gas, even of the best quality, contains at least 56 to 60 per cent. of incombustible gas (CO_2 and N). The gas will therefore scarcely burn when cold, and it is necessary to preheat both the gas and the air for combustion to obtain a high temperature. For this reason Siemens gas cannot advantageously be used for small furnaces, and is impossible for any purpose where an open flame is required; as, for instance, for welding, brazing, or soldering. On account of its great volume and low calorific value it is also not adapted for storage in gasholders, or for being conducted to any considerable distance from the generator. Another important disadvantage is that it cannot easily be purified from the sulphur contained in it. Its utility is, in fact, limited to large furnaces with regenerative firing; but it must be remembered that, though any required temperature may be obtained, this must necessarily be done at a considerable loss of heat, for the reason that all the non-combustible portions of the gas must be raised to the temperature of the flame, and a high heat can be reached only after protracted firing.

Water-gas possesses quite different properties. Its composition averages:—

	Per Cent.
Hydrogen	51·0
Carbonic oxide	42·0
Marsh gas	0·5
Carbon dioxide	4·0
Nitrogen	2·5
Total	100·0

Practically it is therefore all combustible. Its flame temperature is such that a wire of commercial platinum melts in the

flame from an ordinary gas-burner. Its heating power is per volume two and a half times that of producer-gas, and it can therefore be stored in a holder and conducted to any required distance with the same facility as coal-gas. It can be used for all purposes, being equally efficient for the small glass-blowing lamps for the manufacture of electric glow-lamps as for melting of steel in an open-hearth furnace. It is applicable for all heating stoves and furnaces now so extensively used for coal-gas, and for many other purposes for which coal-gas is too high priced to be used.

Water-gas can further be obtained absolutely pure, as the sulphur is contained in the form of sulphuretted hydrogen, which can easily be eliminated by passing the gas through purifiers filled with hydrate of iron, and then consists almost entirely of hydrogen and carbonic oxide.

Leaving the method, manufacture, and properties of water-gas, I will now turn to the results obtained by its application for practical purposes. In doing so, I regret to have to refer almost entirely to experience gained on the Continent. The work of introducing water-gas for various purposes has there been pushed more vigorously than in this country, and the innovation has perhaps also been received with less prejudice than here. At any rate, the introduction of water-gas is far more general on the Continent, and is there making steady progress, water-gas being successively adapted for new lines of manufacture.

Though steel-melting with water-gas is a development of so recent date that the results obtained must not yet be considered as final, it will perhaps be most appropriate to begin with this application, as the achievements so far promise an opening for great improvements and lessened cost.

Some years ago tests were made with a view of introducing water-gas for open-hearth steel-melting at the ironworks of Witkowitz in Austria. Of the results obtained Mr. Albert Sailer, the chief engineer, reported that in a six-ton furnace a quantity of 60 cubic metres of water-gas was used per 100 kilogrammes of steel (1077 cubic feet per cwt.). The time for melting the charge was about the same as by producer-gas firing. To produce the necessary quantity of gas there were at that time required at least 50 kilogrammes of coke, or 50 per cent. of the weight of the steel, a result which necessitated the abandonment

of water-gas firing for economical reasons. By the Dellwik-Fleischer process this proportion would be reduced to about 28 or 30 per cent., which would mean a very great economical difference in favour of water-gas.

But these results have been superseded by a recent installation in a German steel plant near Berlin, which in a striking manner demonstrates the advantages of water-gas firing. Here the charge is melted in *two* hours with a consumption of gas of only 40 cubic metres per 100 kilogrammes of steel, which corresponds to a consumption of less than 20 per cent. of fuel as compared to the weight of steel produced. It is probable that this figure can be still more improved upon in a larger furnace. But it should be noticed that the saving is by no means confined to a lessened consumption of fuel, inasmuch as, on account of the quicker work, the capacity of the furnace is more than double what it would be by ordinary firing. Moreover, the quality of the steel is excellent, so that the product from this water-gas open-hearth furnace finds a ready market as tool steel, fully equalling the best crucible steel, though it is made at a considerably lower cost.

The water-gas open-hearth furnace is simpler and cheaper to construct, as only the air, but not the gas, is preheated before combustion.

The results above given and previous experiences with admixture of water-gas to the producer-gas during the melting have induced two of the largest steelworks in Germany to erect water-gas plants in connection with their open-hearth furnaces. The calculations, which are based on very safe assumptions, show that a very handsome profit is sure to result from this investment. One of the advantages counted on is that for large castings, where the charge of more than one furnace is required, it will be much easier than at present to have several furnaces working, so that their charges will be ready for tapping simultaneously.

An argument which is frequently advanced against the use of water-gas for large furnaces is that the flame should be so short as not to fill the furnace properly, but only produce a local heat, which would destroy the brickwork in one place and leave other portions of the furnace at too low a temperature. Experience

shows that this is not the case. When the heat reaches the temperature of dissociation of steam and carbonic acid, the zone of combustion extends, till the entire furnace becomes equally heated, the flame being visible only as it leaves the furnace. In fact, it has turned out that the only defect of the first furnace constructed was that it was too short.

It might be expected that the wear and tear of the furnace would be excessive, but such is not the case. At any rate, it is not increased in proportion to the increased capacity of the furnace. This may partly be due to the cleanness of the water-gas, which does not carry with it dust or ash, which can act deleteriously on the brickwork.

For crucible steel-melting water-gas has not yet been applied except experimentally, but the results show that in this direction also a very considerable saving may be counted on. In melting phosphor bronze, 100 kilogrammes are melted in *one* hour with a consumption of 45 cubic metres of water-gas, which, by the Dellwik-Fleischer process, may be produced from 20 to 22 kilogrammes of gas-coke, while the same quantity of bronze requires *two* hours and 60 kilogrammes of furnace coke for melting in the ordinary way; thus three times as much fuel and twice as long time.

The application to which water-gas has been most widely adapted is welding of iron plate. No less than nine installations of Dellwik-Fleischer water-gas plants have been made for this purpose within the last two years, and the result has been most satisfactory.

The speed of working averages 33 to 40 feet per day in the manufacture of boiler flues, and the consumption is about 800 to 1000 cubic feet per foot of weld. In most cases the speed of working has been increased from three to five times above what was possible by coke-firing. No less important is the increased comfort of the workmen. The instant the material is heated the gas supply is cut off and the flame ceases. There is no work in keeping the fire in proper condition by removing clinkers, or waiting for the heat to come up after fresh fuel has been filled on the fire; also the labour of bringing in fuel and carting away refuse is done away with.

In this country the use of water-gas for welding is limited

mainly to the manufacture of boiler-flues and tubes. On the Continent the application is more varied. Thus a German works welds masts for war-vessels, and has turned out cylinders of 140 feet in length and 10 feet in diameter in one piece. At a Swedish boiler-shop welded fireplaces for vertical boilers are a specialty. At the same place the entire smith forge has been converted to gas-firing, with some saving in fuel and more in time, and a great increase in cleanliness and comfort, which is greatly appreciated by the workmen.

For brazing and soldering water-gas has been applied on a considerable scale and with the best success, and is so used, for instance, in the manufacture of bicycles, storage tanks for compressed gas, &c.

In the manufacture of cutlery, water-gas is apt to find a large field of utility. Not only can the forges be more evenly and economically heated, but for the tempering and annealing furnaces there is no better fuel. An installation for such purpose of a Dellwik-Fleischer water-gas plant has proved so successful that the gas-generating plant has later been doubled by erection of a second generator.

A large cutlery manufactory in the United States introduced water-gas firing some years ago, and though the process of gas production was not as economical as is obtainable at the present time, yet the advantages were very marked as regards economy and convenience, as well as in the quality of the work obtained.

Water-gas is applicable for a number of other purposes in the metal industries, too numerous to be described in detail. So, for instance, in pipe-foundries a very considerable saving in fuel is obtainable in drying the moulds by means of water-gas burners. In welding chains a high degree of economy, lessened labour, and a more reliable product will result. In welding of pipes and pipe fittings water-gas will prove to offer very material advantages over present methods.

Water-gas is also rapidly gaining ground in other industries than those connected with the working of iron, steel, and other metals. An installation for glass-melting has proved very successful; glass-blowing for the manufacture of ornamental glassware and electric glow-lamps is done quicker and much

cheaper with water-gas than with coal-gas; furnaces for carbonising the fibres for electric glow-lamps are worked more cheaply and easily than with other fuel.

Enamelling, singeing, drying, &c., are also purposes for which water-gas has been adapted.

It is further making its way into the chemical industries, several plants for such purposes being in course of construction. At a chemical manufacturing works in Germany a water-gas plant is being erected as a central station for supply of heat, power, and light for the entire establishment.

The conversion of all the fuel into gaseous form at one place, and the distribution of the gas from this central station to the different furnaces and other places of consumption, is a principle which ought to recommend itself in all industrial establishments where large quantities of fuel are used, which will otherwise have to be carted around to a number of different places, involving labour and waste. Such a central gas-producing plant would also supply the cheapest means of generating power. For one horse-power are required 30 to 35 cubic feet of water-gas per hour, and, as has already been shown, this quantity of gas is produced from less than 1 lb. of coke. The efficiency of gas-engines of small size is very nearly the same as that of large ones, which is not the case with steam-engines, and a system of water-gas plant and gas-engines therefore allows of a distribution of power far cheaper than is possible with steam-engines, and elaborate transmissions with shafts and belts.

In addition, lighting by incandescent water-gas burners is the cheapest illuminant obtainable, and offers also other advantages over the same kind of lighting with coal-gas, as the flames burn more steadily, and the mantles can be made stronger. Some installations of "blue" water-gas for general distribution have been made on the Continent, and the results have proved very satisfactory.

I have earlier referred to the introduction of carburetted water-gas for general distribution as admixture to coal-gas. This system has met with a great deal of favour during some years past, but lately labours under the drawback of advanced prices of oil. On the Continent a high duty on petroleum has practically prohibited water-gas enriched with this material. But at the

present time the price of benzol has gone down in such manner as to make it a very cheap enricher, and a number of plants on the Dellwik-Fleischer system with benzol enrichment have been built, or are being built, as auxiliary to coal-gas works. This subject has recently been treated at length by Professor Vivian B. Lewes in his lecture on "Water-gas and its Recent Continental Developments," at the meeting on May 2nd of the Incorporated Institution of Gas Engineers.

These examples of the general utility of water-gas, when made by the present economical process, might easily be multiplied, but doing so would, to a great extent, mean repeating the qualities which make it so desirable in the instances I have specially mentioned.

I have previously alluded to the advantages in industrial establishments of having a central gas plant for generation of heat, power, and light. But this idea might be adapted on a larger scale. Nobody who on a winter's day looks out over a thickly settled town can fail to be impressed by the fact that it is not the chimneys of the manufactories that produce the bulk of the smoke which hangs over the town, but that the numberless domestic fireplaces are the chief offenders. In these cases it is hopeless to try to introduce smoke-consuming devices. The only remedy is gas-firing. Though gas-firing is becoming more and more general, it cannot be expected that coal-gas, as manufactured at present, will be able to supplant solid fuel to any great extent. To accomplish this purpose it is necessary to convert, not 20 per cent.—as in the case of coal-gas—but 80 per cent., or if possible more, of the heating value of the fuel into gas. In the present state of the gas industry there is but one way of accomplishing this, and that is to make coal-gas and convert the residual coke into water-gas and mixing this to the coal-gas.

On account of the higher efficiency attained by gas-firing, the same amount of heating could be accomplished by the expenditure of about one-third of the fuel used at present for domestic heating, cooking, &c., while the saving of the other two-thirds ought to easily cover the cost of producing and distributing the gas. Even if a change of this character should not cause any very great saving of cost to the private consumer, the cleanliness and lessened labour ought to be highly appreciated by everybody,

while the saving of raw material and the abatement of the smoke nuisance are objects of no small national importance.

The distribution of a cheap gas of low illuminating power for purposes of heating, power, and lighting by means of incandescent burners is perhaps an ideal not to be realised for a long time to come, but no doubt the economical conversion of fuel into water-gas is a step in the right direction for future development.

DISCUSSION.

Mr. R. M. DAELEN (Düsseldorf) said that he had been somewhat interested in the introduction of water-gas for application to open-hearth furnaces, but he had found a difficulty with respect to the use of coke. He was told afterwards that experiments were being made to produce the Dellwik water-gas by coal, and he would like to ask Mr. Dellwik if his experiments were now complete.

Sir LOWTHIAN BELL, Bart. (Past President), had nothing to remark with regard to the subject, except to remind the members of the Iron and Steel Institute that this was the second time that the question of water-gas had been brought under their notice. The first time was in Paris, where it was announced that the reign of water-gas had come, never to depart from amongst them. He had taken the opportunity then of dissenting from that view. He thought that the production of water-gas was necessarily attended with considerable loss of heat. It was true that in respect of water-gas the free hydrogen which it contained was the most valuable heat-producing element in nature, and on the other hand it was to be remembered that the consumption of heat in order to effect the dissociation of water was exactly equal to the quantity of heat evolved when the liberated hydrogen was burnt. Therefore practically the announcement then made meant that something was going to be made out of nothing. In other words, energy was to be created without any expenditure of fuel, which was a physical impossibility. With regard to the gas produced from the ordinary producer of the Siemens furnace, he was not quite convinced that dilution by nitrogen was attended with all the difficulties and inconveniences mentioned; and upon the present occasion it was a vehicle by which heat was returned to the furnace, thereby proving that it played a very useful part.

Mr. H. BAUERMAN said that he with some other members of the Institute had had an opportunity of seeing the arrangement at

the electric works of Mr. John Hammer in Sweden, and those who witnessed it were very much impressed with the beauty of the apparatus, and also with the excellent quality of the gas produced, which was used for the delicate purpose of glass-blowing. Therefore he was glad to hear the paper; but he was rather puzzled as to how the author was enabled to burn the gas to the minimum required, and to get all the sensible heat in the carbon coal itself. He supposed it had really something to do with the apportioning of the column of fuel in the closed place above termed the combustion chamber; but at any rate, he thought it would be a good thing if the author gave them a little more information about that.

Mr. ALEX. E. TUCKER (Birmingham) said that the gas would lend itself with particular advantage to the working in some of the trades of Birmingham with which he was somewhat familiar, and he would be glad of some information as to details that the author might be able to supply in connection with the application of gas to tube-welding. It might be common knowledge that in Birmingham, and perhaps elsewhere, the gas was mixed in the blower and passed along the tubes to the burners, where it was blown under pressure on to the work to be welded. In the paper the author said that the flame temperature was such that a wire of commercial platinum melted in the flame of an ordinary gas-burner; he (Mr. Tucker) pointed out, however, that a platinum wire, if very fine, might be melted in an ordinary Bunsen flame. If the conditions of welding, such as the author indicated by this statement and also in other parts of his paper, were such as to dispense with the use of blast under pressure, and the naked flame was sufficient to effect the welding, that he thought was a consideration which should lend itself particularly to economical and most useful application.

Mr. WILLIAM DEIGHTON (Leeds) said that he had had rather a considerable experience in the manufacture of water-gas, and that he could corroborate almost everything that Mr. Dellwik had stated. He had investigated the subject to a considerable extent, so much so that they were now putting down the Dellwik process for water-gas making. He was at present

using water-gas in the usual way, that was, taking a run of seven to eight minutes on producer-gas, then two and a half to three minutes on water-gas. Previous to putting that installation down he had made many inquiries from the members of the Iron and Steel Institute as to the result of using producer-gas if collected and washed, and as to its efficacy, and he had received some very discouraging replies. However, his ideas were fixed, and in putting down his water-gas installation he put two very large gas-holders down, of a capacity of something like 45,000 cubic feet. One held the water-gas and the other producer-gas. In the case of the producer-gas he passed it through scrubbers into the gas-holder, and to his astonishment they got a most intense blue flame. Any gentleman in the room could verify it. From the water-gas generator he got something like 32,000 cubic feet of water-gas per ton of coke, and two-thirds of the whole of his steam-power from the producer-gas. He did not know about any other installation, but the result was certainly as satisfactory as could be hoped for. He did not know whether by using the Dellwik process he could get any greater economy, because it would seem at present they did not lose practically a unit of heat, because every particle of the gas produced was burnt under the boilers, giving an intense blue flame, and they could see that flame for a length of 15 to 20 feet. They used, as perhaps many present were aware, water-gas for welding tubes, and they had welded tubes of $1\frac{1}{4}$ inch iron, and they had made a perfectly solid cylinder $1\frac{1}{4}$ inches thick. Therefore he thought they could see from that the splendid efficacy of water-gas in welding operations. His own experience in applying water-gas to the Siemens furnace had not been of the most satisfactory character, but he thought that was due to the want of knowledge. There was a local application in water-gas, and when they could make and elongate the water-gas flame like the flame that was obtained by coal-firing, then its application would be multiplied tenfold what it was at the present time. He would be very pleased to show it to any one who liked to see it.

Dr. LUDWIG MOND wished to ask Mr. Dellwik a question. Mr. Dellwik stated in his paper that the most reliable result which had been obtained at the works where his plant

had been working for a considerable time showed that 75·2 to 77·7 per cent. of the calorific value of the fuel was obtained in the form of water-gas. He wished to know whether these 75·2 to 77·7 per cent. did or did not include the fuel used for steam-raising in those works. Somehow or other that point was never made quite clear in the paper. Professor Lewes had stated, and this statement was quoted in the paper, that an 80 or 82 per cent. efficiency was obtained, taking into calculation the fuel used for making steam, figures which must necessarily surprise any one having any acquaintance with the subject. Mr. Dellwik gave 75·2 to 77·7, and, as far as he could understand from the paper, without including the fuel used for raising steam. This made a very great difference, and he would like to have the point made perfectly clear.

Mr. DELLWIK in reply said, that in regard to Mr. Daelen's question about the production of water-gas from coal, he had constructed water-gas generators for this purpose a number of years ago in America, where they worked successfully for several years with many different kinds of coal. But that method was not readily applicable to the present process, which was more economical, and they were now making experiments for perfecting a new coal-generator. The experiments, though very satisfactory, were not completed, and they were therefore not yet prepared to bring them before the public, as there were a number of mechanical details to be worked out.

There had been a question asked, how the combustion of the carbonic acid was produced in the water-gas generator during the blow. The combustion, so far as he understood the matter, did not depend only on the materials which came into contact with each other, but, like any other chemical reaction, also on the proportions in which they met and the time during which they remained in contact with each other. In fact, it was the question of time and proportions which laid the foundation for the whole invention. The air might pass through the bed of fuel in the generator so quickly as not to give time for reduction of carbonic acid, already formed, into carbonic oxide, because of the presence of a surplus of oxygen, which would not be completely consumed until in the top layers of the bed of fuel. Thus the

higher degree of oxidation, with consequent economy in heat, was obtained.

For tube-welding, water-gas had been introduced, as Mr. Deighton had just mentioned, at his works and at many other works, for the manufacture of boiler flues and similar articles. For pipe-welding, one of the places where it was used was at the German Tube Company's works at Düsseldorf, where they welded all tubes of more than 7 inches diameter with water-gas. For smaller pipes water-gas had not yet been adapted, but he thought that the furnaces for this purpose would show a considerable economy over the present furnaces if water-gas were employed.

In regard to the temperature of combustion of water-gas, the water-gas which was produced by the Dellwik-Fleischer process was exactly identical with the water-gas produced by the older processes. The heat of a small flame, such as burnt from an ordinary gas-burner, was very high, because the stream of gas that issued from the burner was so thin as to come into very intimate contact with the air, thus creating a very perfect combustion. In the case of a large flame, such as would be used for welding, the stream of gas was too thick for the air to penetrate to its centre and create the same intense combustion, and it was therefore necessary to use an air-blast. In that way they got a perfect mixture of air and gas, and they got the same, or even a higher, flame temperature than they did with the small open flame.

Mr. Deighton referred to the use of producer-gas in his boiler plant. He (the speaker) mentioned in reading his paper that that had been done at some installations of the old system of water-gas production, and he must say that the application which Mr. Deighton had made in that respect was the finest he had ever seen anywhere. But even if there was comparatively little loss of heat in this manner, there could scarcely be as good utilisation of the heat of the fuel in that way as by converting it all into water-gas. He thought they would agree with him that, when they built a generator for the production of water-gas, it was more desirable that *only* water-gas should be produced, and not a small quantity of water-gas and a large quantity of producer-gas, which was only a troublesome bye-product. It contained more of the heat value than the main product itself, and besides it was not possible in every place to make the same

profitable utilisation of it as in Mr. Deighton's works, for the reason that the consumption of producer-gas would not be exactly in the same proportion as it was generated.

Dr. Mond had inquired about the efficiency of the generators, and whether the figures given included the steam-coal. In Professor Lewes's reports that was included, and the reason why so high a figure was obtained was that he had taken the heat of combustion to liquid water; whereas in the figures that he (Mr. Dellwik) had given the heat of combustion was calculated only to steam of 100° C. This would account for the very high value which Professor Lewes had obtained on his test. It had been said in the paper that the yields referred to were calculated per pound of carbon contained in the coke which was charged into the generator, so that that did not include the steam-coal. Better results could not reasonably be expected in a plant running intermittently for ordinary work, even if a higher yield were easily obtained by a carefully conducted test. In the works he had referred to (the Königsberg Gasworks), the generators were working between ten and sixteen hours a day, and stood idle during the night.

Sir LOWTHIAN BELL asked to be allowed to put a question to Mr. Dellwik. He would ask whether, if the water-gas was applied to boilers, there was any gain of economy?

Mr. DELLWIK replied that he had had many inquiries about water-gas for boiler-firing, but as steam boilers as a rule permitted of very good utilisation of the solid fuel, and as a cheap grade of coal was commonly used for the purpose, he had invariably replied that in such conditions he did not think that water-gas from coke would offer any economy in the cost of the fuel. That was, however, a question of the relative cost of different kinds of fuel, and there might be cases where water-gas would be more economical, especially when the lessened labour was taken into account.

A hearty vote of thanks for his paper having been accorded to Mr. Dellwik, the following paper was then read:—

THE UTILISATION OF BLAST-FURNACE SLAG.

BY THE RITTER CECIL VON SCHWARZ.

MUCH has been written, suggested, and experimented on the important subject of utilising blast-furnace slag.

The gradual enlargement of blast-furnaces has also considerably increased the quantity of their product, not alone of pig iron, but also of their principal by-product, namely, slag. To dispose of the large quantities of blast-furnace slag turned out in a proper and economical way has caused a good deal of study, trouble, and, in some cases, even embarrassment, to our blast-furnace managers.

The use of blast-furnace slag for sand bricks and cement, even the utilisation of the heat stored up in the hot liquid slag, has been suggested, and in several cases has been carried out. But the fact that large quantities of blast-furnace slag still remain unused serves to indicate the want of success of the methods hitherto employed for utilising it.

A few isolated results were obtained some time ago with blast-furnace slag cement, giving rise to hopes that now the important question of utilising blast-furnace slag in a proper and satisfactory way was solved; but it soon turned out that the slag cement was of a somewhat untrustworthy quality, and the consumers consequently abandoned it in most cases.

Only quite recently a method has been employed to manufacture cement out of blast-furnace slag which has given everywhere the best results with reference to strength, voluminal constancy, and reliability. This method has recently been employed in Germany and Belgium with great success, and is briefly as follows:—

The slag is granulated by letting it run into a cast iron trough, inclined to one in ten, where a strong current of cold water flows.

The granulating of the slag has a considerable advantage

with reference to its use for cement-making, as it turns it at once into small sand of a very brittle nature, thus preparing it in a high degree for the necessary pulverising process coming hereafter. Besides this, the slag experiences by granulating chemical changes also favourable to the same purpose, the principal of these being the decomposition of the sulphide of calcium contained in the slag, as the latter is very injurious to cement. The calcium combines with the oxygen of the water to form lime (CaO), whilst the sulphur forms with the hydrogen of the water sulphuretted hydrogen gas (H_2S); thus: $\text{CaS} + \text{H}_2\text{O} = \text{CaO} + \text{H}_2\text{S}$.

The slag sand is removed by a perforated bucket lift and transported by means of a short wire-rope tramway to the drying stoves. These consist of long sheet iron drums slightly inclined, and angles rivetted inside all along; the flame enters the drum on the lower part and leaves it on the other (higher) end. One such drum is capable of thoroughly drying 30 tons of slag sand, containing about 25 per cent. of water, in twenty-four hours.

The slag sand, thus dried, is now mixed about half and half with limestone of a good quality, broken up into pieces of about a fist in size. To this mixture about $3\frac{1}{2}$ per cent. of powdered slacked lime is added, and the whole converted into powder of such fineness that not more than $2\frac{1}{2}$ per cent. of residue remains on a sieve with 5000 meshes per square inch, and not more than $12\frac{1}{2}$ per cent. on a sieve with 30,000 meshes per square inch. As it is very important, for the cement to turn out a success, that a thorough mixture of the raw materials (namely, slag, limestone, and slacked lime) takes place, the fineness of the grain is controlled twice a day and any discrepancies remedied at once.

The grinding into powder is effected by means of a cylindrical ball-mill for the coarse grit, followed by a so-called tube finishing-mill for the fine powder. One cylindrical ball-mill together with a tube finishing-mill produce about 60 tons of powdered raw material in about twenty-four hours, and consume about 45 horsepower both together.

The following is an analysis of the blast-furnace slag sand and of the limestone:—

1. *Slag Sand*—

	Per Cent.
Silica	30 to 35
Lime	46 „ 49
Alumina	10 „ 14
Ferrous oxide	0·2 „ 1·2
Magnesia	0·5 „ 3·5
Sulphuric acid	0·2 „ 0·6
Manganous oxide	3 „ 4

This slag sand was produced from a blast-furnace turning out grey pig iron.

2. *Limestone*—

	Per Cent.
Calcium carbonate	97
Magnesia	0·5
Silica	1·6
Alumina	1
Sulphuric acid	0·06

The powdered raw material (slag sand, limestone, and hydrate of lime) are now mixed with about 8 per cent. of water and made into bricks, each weighing about $7\frac{1}{2}$ lbs., by means of a press, the latter producing about 30,000 bricks in twenty-four hours, and consuming, including the mixing apparatus, 16 horse-power.

These bricks are stacked in the open and left there for about three to four days, when—owing to the presence of hydrate of lime—they get a certain amount of resistance, after which they are charged into a kiln to be burnt into clinker. The burning is effected in kilns of a particular construction and very well adapted to the purpose.

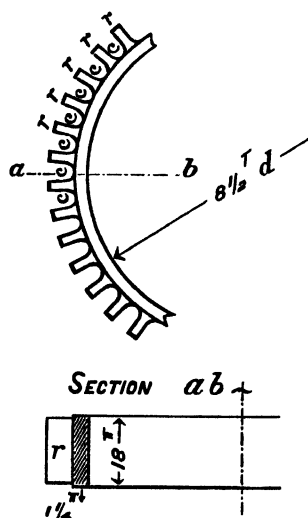
Each kiln consists, in its essential part, of a series of rings, each 1 inch to $1\frac{1}{4}$ inch in thickness, $8\frac{1}{2}$ feet inner diameter, and 18 inches in height. These rings are provided outside with ribs (*r*, Fig., p. 144), and placed in such a way, one above the other, that the vertical ribs cover one another, thus forming little vertical channels (*c, c, c*), all around, in which the air circulates from below to the top, like in a chimney, thus continually cooling the cast iron rings from outside, and preventing them from getting over-heated. The materials to be burnt are in direct contact with the cast iron rings, no lining of any kind being provided for. There are eighteen such rings,

put one above the other, the upper rings—where the greatest heat occurs—being hooped at the joints. The top of each kiln is provided with a cone and a chimney made of sheet-iron, 3 feet in diameter and 30 feet in height. The cone has four charging-doors, which can be closed by sheet-iron covers as soon as the charging is done.

At a depth of 12 feet from the top the inner diameter of the kiln is lessened to nearly half its inner horizontal section, and on this place provided with a double row of tuyeres to admit compressed air, this arrangement having for its object to

burn any carbonic oxide or carburated hydrogen gas arising from below as completely as possible, as well as to concentrate the heat exactly where it is required, viz., on the place where the formation of the clinker is to take place.

Compressed air is also introduced from below in two places. The compressed air is produced by a ventilator, the pressure being $\frac{3}{4}$ inch to $1\frac{1}{4}$ inch of water. One charge consists of 100 bricks and 65 lbs. to 70 lbs. of coke as fuel; one-third of the coke could be replaced, if necessary, by anthracite or maigre piece-coal.



As a rule, four kilns are arranged in one set, being provided with a common lift and a common platform for all four kilns together. They are surrounded by a scaffolding made of angles and tees, on which the staircase to mount the platform is fixed. At the same time corrugated galvanised sheets are rivetted on this scaffolding all round, in order to prevent unequal cooling of the furnaces outside in case of rain, wind, or snow.

The principal advantage of a kiln of this description is that, owing to the continuous and regular cooling from outside, the fritted clinker cannot clog the interior of the furnace, thus ensuring a regular and continuous working of the furnace. The ribs at the same time give strength, and prevent the cast

iron rings from warping. Each furnace produces about 25 tons of well-burnt clinker, equal to as much finished cement, in twenty-four hours.

A little water is poured over the clinker after being drawn from below, in order to change any quicklime having formed itself, owing to imperfect grinding and mixing of the raw materials, into hydrate of lime, as well as to cool the clinker. The clinker is now stored in a covered shed for about six weeks' time, and then ground into fine powder by means of a cylindrical ball-mill, followed by a tube finishing-mill, viz., in the same way and under the same rules as described before with regard to the grinding of the raw materials.

The following is an analysis of the finished cement :—

	Per Cent.
Loss on ignition	5·70
Silica	23·70
Lime	59·08
Alumina	6·14
Ferric oxide	1·80
Magnesia	1·40
Sulphuric acid	1·30

This cement is distinguished by its exceptional high strength of compression and tensile strength, especially after a longer period of hardening. For instance, a mixture of one part of cement with three parts of sand showed :—

After 28 days.

Tensile strength	282 to 370 lbs. per square inch.
Strength of compression	2560 „ 2920 „ „

After 360 days.

Tensile strength	538 to 700 lbs. per square inch.
Strength of compression	4260 „ 5760 „ „

As to the economic view of the question, the following figures may serve for information :—

Prices of the raw materials.

(a) Blast-furnace slag sand	1s. 3d. per ton.
(b) Limestone	2s. 0d. „
(c) Coke	40s. 0d. „

All delivered free at the works.

(d) Cost of production per ton of cement at the works (including general expenses, depreciation, &c.)	18s. 0d. „
(e) Sale price per ton of cement	32s. 0d. „
1900.—i.	K

A slag cement factory provided with a set of four furnaces and other appliances to correspond produces from 25,000 tons to 30,000 tons of cement a year, and requires from 250 to 300 horse-power to work it.

The above figures, analyses, &c., are taken from a cement factory which has successfully employed the above-described method for the last three years. The quality of the cement is so much valued that they have already sold this year's and the half of next year's production in advance.

DISCUSSION.

Sir LOWTHIAN BELL, Past-President, said there were many present who were probably more experienced than himself in the details of making hydraulic cement. He would have to confess, speaking of what they were doing at Skinningrove, where works of that kind were situated, that it seemed to him a very much more simple process there than that described by the author of the paper; and when he came to see the cost of the material when made, he thought his friends must make their cement a great deal cheaper than the cement referred to in the paper.

The PRESIDENT said that the question of the utilisation of slag, in view of the enormous amount produced, was one of great importance, and he hoped there would be an exhaustive discussion upon it.

CORRESPONDENCE.

Mr. W. E. BUESCHE (Brussels) sent the following contribution to the discussion:—

The principal advantage of the process referred to results from the fact that a real "Portland cement," and not a so-called "slag cement," is obtained by the new invention. The excellent qualities of this Portland cement are principally due to the very high hydraulic qualities of granulated blast-furnace slag. In addition to this, the new process offers to the manufacturer the most important advantages with reference to the consumption of fuel and labour, these two items being from 30 to 40 per cent. less if Portland cement is made of blast-furnace slag (as described), as compared with any of the other methods hitherto in use for the manufacture of Portland cement. This considerable saving of from 30 to 40 per cent. in the cost of production may easily be understood from the fact that the granulated blast-furnace slag, having already passed through the high temperature of the blast-furnace, cannot undergo a new

loss on ignition in the cement kiln, whilst the ordinary raw materials used for cement-making, such as clay, limestone, &c., endure about 40 per cent. loss on ignition in the cement kiln. Besides these great advantages offered to the manufacturer, others of still higher importance will be ensured to the proprietors of the blast-furnaces, namely:—

1. The whole working power required by such a cement factory may be supplied by engines worked with blast-furnace gases.

2. No more valuable space is taken away for the cinder-tips.

3. Even the old cinder-tips may conveniently be utilised for the erection of cement works.

To sum up, this invention is of the greatest economic value, as it creates new value out of waste materials hitherto quite worthless, thus strengthening the ironworks in their struggle against foreign competition, which gets more and more difficult every day. Of importance is also the fact that with this invention a great many different kinds of blast-furnace slag, not at all fit for the manufacture of "slag cement," can be utilised by the new process. All kinds of basic blast-furnace slag may be employed in manufacturing "Portland cement" by the new process.

Mr. CHARLES WOOD (Middlesbrough) wrote:—

I was sorry I was unable to be at the meeting when the Ritter Cecil von Schwarz read his paper on "The Utilisation of Blast-furnace Slag," as there are a few points upon which I should have liked further information.

It has been known for some years that a good cement has been made from blast-furnace slag in Germany and Belgium, but whether this cement is equal to the tests exacted by English engineers it is difficult to say; but the chief point in its favour is that for ordinary purposes there is not much difference, and second (which goes a long way) is that it is sold in this country at a cheaper rate. This points to one of two things, viz., either the English cement-makers must be making a large profit, or else the Germans must have very cheap labour and be content with less remuneration.

We will just see how the process of manufacture compares

with slag cement made at Skinningrove and Portland cement as carried out in this country. I understand from the paper the German system to be as follows :—

First, the slag sand is calcined or burnt in a Ransome's rotary cylinder, in order to drive off all the water held in a spongy cellular slag sand, and the small amount which may have combined with the sulphur and lime.

Second, this calcined slag sand is now mixed with about half-and-half of raw limestone, which has to be broken up into small pieces (which certainly costs something). This mixture is put into a ball-mill and ground to a fineness of 30,000 meshes to the inch, to which is added about $3\frac{1}{2}$ per cent. of slaked lime.

Third, this material is now made into bricks, which have to be stacked and kept to harden.

Fourth, these bricks are now burned into clinker in a specially constructed furnace or kiln.

Fifth, the clinker, after it is drawn from the kilns, is watered and stored for six to eight weeks, and again ground into a very fine powder in a ball-mill ; and

Sixth, finished in a tubular mill.

Compare these six different operations with the simple way in which Portland cement is manufactured by the English makers, or with the way the manufacture of slag cement is carried out at Skinningrove blast-furnaces, which consisted simply of reducing the slag by blowing it into shot as it flows from the blast-furnaces, and then mixing it with fine powdered slaked lime and grinding it in the ball-mill to about the usual fineness of Portland cement.

The cost of the raw material is about the same in each case ; if anything, in favour of the English houses. It would therefore seem absurd to suppose that the German mode of manufacture could be carried out here in England so as to allow a fair margin of profit.

It may be interesting here to compare the analysis of slag cement as given in the paper with English and also Portland cement :—

Principal Constituents.	German Slag Cement.	English Slag Cement.	Portland Cement.
Lime	59·00	46·00	60·00
Alumina, &c.	8·00	20·00	9·00
Ferric oxide, silica	23·70	25·00	22·00

The remarkable difference in these three analyses would naturally call for the remark that the cements cannot be of the same value in use, but there is no very great practical difference. Some cements take up more water of crystallisation than others, and this is more so when the percentage of oxides and alumina are in excess, and this may somewhat equalise the difference.

The remarkable hardening effect of oxides of iron in conjunction with lime, silica, and alumina is well exemplified in the Italian puzzolanas, where, as in the best qualities, the lime is actually as low as 8 per cent., whilst the oxides of iron run up from 12 to 15 per cent. This hardening effect of oxides of iron induced the writer to employ the dust from the ironstone heaps, or from the calcining kilns, or spent pyrites from the chemical works, in conjunction with slag sand, wet direct from furnaces, ground up together with slaked lime in order to make a strong liquid cement or mortar.

The following proportions were used :—

	Per Cent.
Slag sand	40
Slaked lime	30
Spent pyrites or calcined ironstone	30
	100

There is quite sufficient water held in suspension in the slag sand to make the cement or mortar wet enough without adding any more, and if this is mixed up with broken slag shingle, say about the size of walnuts, leaving all the small in, and put straight away into foundations or walls, being slightly rammed down in about 8 to 10 inch layers, it will form a splendid concrete, equal to good Portland cement concrete, at about one-third or one-fourth the cost.

I may say I have made thousands of cubic yards of this for machinery foundations and walls. The entire building of the

Cleveland Slag Works was made of this material, which was only lately demolished in consequence of the dock extension at Middlesbrough, and the contractor will give his account of the difficulty he had in removing the underground work.

From this it will be seen that any one within the reach of slag sand and ironstone has the means of making a cement for concrete or a mortar for walling or building at a cost of one-third or one-fourth of the ordinary methods; but it must be used immediately, as it sets so quickly.

It may be also mentioned that this cement or mortar is perfectly hydraulic. The chemical action of the lime, iron, and sulphur is so quick that if ground fairly fine it will become quite warm. The water taken up as water of crystallisation by this mortar or cement is unusually large, and confirms my previous remarks on the subject.

At the Cleveland Slag Works the manufacture of Portland cement from slag was discontinued in consequence of the difficulty of reducing the slag to a fine powder, the sharp cutting nature of which destroyed any grinding mill employed in a few hours; and it was only through the invention of the pounding action of the ball-mill which has enabled slag to be reduced to the required fineness economically.

The remarkable prominence in which the author of the paper introduces his kiln for making clinker suggests to the writer of these notes that the title of the paper might have been changed somewhat to the following, "A New Kiln, and the Utilisation of Blast-Furnace Slag." This kiln certainly seems to have one or two points worth notice, however, viz., that inside a series of cast-iron rings, of which a sketch is given, a temperature is maintained equal to molten clinker, whilst the rings are kept sufficiently cool to prevent their warping or melting by air on the outside. I should be afraid that the wear and tear on these rings must be rather severe.

Messrs. J. C. Johnson & Co., of Gateshead and London, very large Portland cement-makers, say that the German system of making cement would be ruinous in this country, and that great improvements in the manufacture of Portland cement are now being carried out which will prove very economical.

The RITTER CECIL VON SCHWARZ asked to be allowed to state that the cement he referred to in his paper was burnt cement. It was not the kind that was usually called slag cement, but really Portland cement.

The PRESIDENT said that it only now remained to offer a hearty vote of thanks to the Ritter Cecil von Schwarz for his exceedingly interesting paper.

The PRESIDENT then said that he should like, on behalf of the meeting, to say how glad they were to see Mr. Andrew Carnegie here.

Mr. ANDREW CARNEGIE, Vice-President, said: Mr. Chairman and gentlemen, I am equally surprised and gratified at such an unexpected and undeserved tribute as is implied in the proceedings of this meeting being interrupted by any reference to my humble self. I regret that our late arrival at Southampton prevented me from being present at your banquet last night, where I was to make a speech; I did not know upon what subject, but the proper condition for a man to be in when he rises to speak at a banquet after dinner is not to have the slightest idea of what he is going to say. Serious problems are discussed here, however, in the mornings, and the very reverse must be the state of the man who has to speak upon these. I think no man will ever attempt more than once to rise in your presence who has not thought very seriously upon every word which he is about to utter and made himself master of his subject. I congratulate you, gentlemen, upon the prosperity of the iron and steel business. I suppose we have never had such a prosperous year in recent times upon both sides of the Atlantic, and I hope you have all made handsome returns, and even in some cases fortunes, or are in line to do so. I trust the prosperity you and we now enjoy is not to meet with any sudden reversal. I do not believe it will. To my mind it seems clear that the wants of the world for steel must increase rapidly year after year, and ensure a continuance of such a degree of prosperity as will yield a deserved return upon the capital, ability, and

attention which you in the iron and steel industry have to bestow in order to reach anything like satisfactory results. I thank you very much for your kind reception.

A vote of thanks having been accorded to the Ritter Cecil von Schwarz, Mr. Joseph H. Harrison then read the following paper by himself and Mr. Lawrence Gjers :—

THE EQUALISATION OF THE VARYING TEMPERATURES OF HOT BLAST.

By LAWRENCE F. GJERS AND JOSEPH H. HARRISON, M. INST. C. E.,
MIDDLESBROUGH.

SINCE the introduction of the Cowper and other forms of regenerative hot blast stoves, it has been the custom to let the hot blast enter the furnace as it left the stove, and as this in some cases means at a temperature varying from 1200° F. to 1500° F., it is quite evident that the steady working of the furnace must be interfered with.

Now, the apparatus here described consists of practically another small stove with a central division wall. It is filled with chequer-work, and the hot blast, entering at one side of varying temperature, is delivered out at the other side at an even *mean* temperature.

This apparatus, a short time after it is first put into operation, arrives at the *mean* temperature of the hot blast, and it is intended to make it of sufficient size that, in the ordinary way of working, half of it always remains at this temperature, and the other half gives and takes according to the varying temperature of the hot blast entering.

Assuming that the variations in temperature are, say, 200° F., or a maximum of 1400° F. and a minimum of 1200° F., and that the stove's run is one hour, it is evident that during the first half-hour the apparatus will absorb heat from the hot blast, which is being delivered to it at 1400° down to 1300° .

At the end of the first half-hour the whole of the apparatus will be at about the mean temperature, viz., 1300° . During the next half-hour, as the temperature of the entering hot blast runs down from 1300° to 1200° , it absorbs the heat which had been deposited in the apparatus during the first half-hour, when the temperature of the entering hot blast was between 1400° and 1300° .

Now, look at the equaliser after the stove has run one hour,

and you will see that the first part encountered by the hot blast has been cooled down to say 1200° . Directly the next stove is put on and the hot blast at 1400° strikes this chequer-work, part of its heat is given up, only to be given out again at a later period of the stove's run.

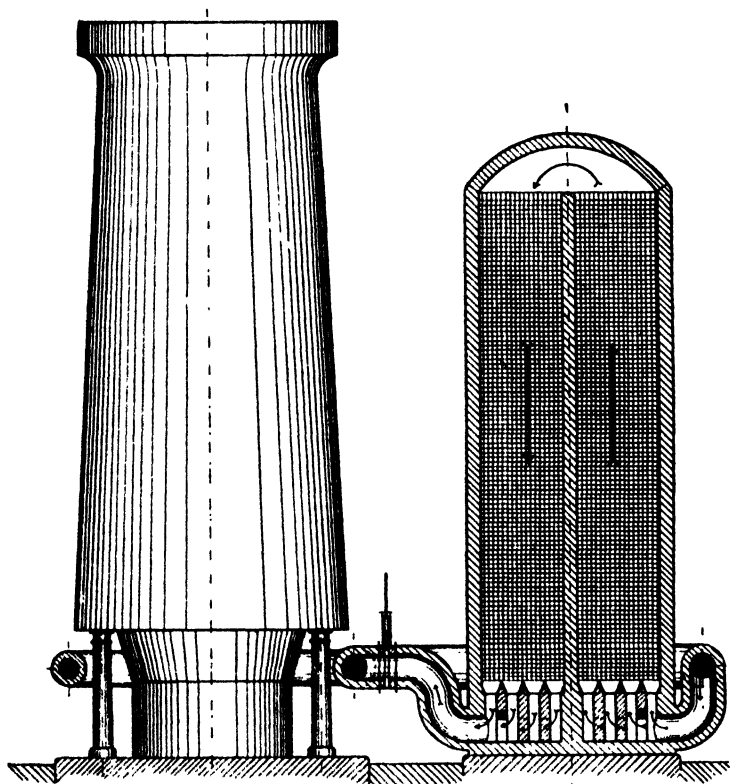


Fig. 1.

There are times when the variation in temperature is more than 200° . Take the case of a new stove and an old one, or a clean stove and a dirty one, working on the same furnace. Under these conditions the maximum might be 1500° and the minimum 1100° .

The equaliser is made large enough to deal with these extremes,

and also acts as an accumulator of heat; so that if at any time the necessary temperature is not got in the stoves owing to bad gas for short periods, there is a large storage to be drawn upon.

This means that instead of the heat jumping down in one hour, that it would go down gradually over a much longer period, and the effects would not be so sudden upon the furnace.

Now, what has been done before in this direction? Nothing

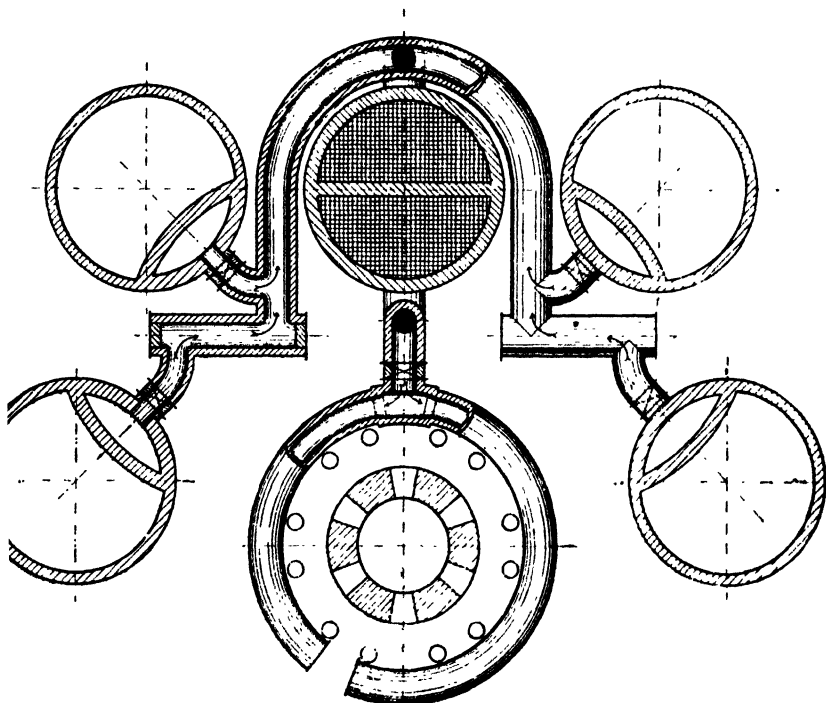


Fig. 2.

has been attempted, as far as the authors of this paper are aware, in the way of *equalising*—that is, arriving at a *mean* temperature; but in America, and perhaps in other places, it is the practice now to *level* the heats by means of cold blast. This is done by admitting sufficient cold blast into the hot blast main to keep the heat down to a point which can always be obtained from the stoves. When the stoveman puts a freshly heated stove on to blast, he opens a cold blast valve to the hot blast main till he

finds he has got the heat down to the right point, and as the stove's run continues, he gradually closes the cold blast valve till he finds it is quite shut, and then he puts that stove off and a fresh one on.

In this way a regular heat is kept, but it demands the careful and constant attention of the stoveman, and it is obtained at the expense of reducing down to the *minimum* temperature, with the risk of bringing it much below if proper attention is not given by the workman. It seems no use to put up good apparatus to heat the blast and then to reduce it down again.

By this *levelling* process, if the variations were 1400° to 1200° , the furnace would be worked at 1200° ; but with an equaliser it would be worked at 1300° or 100° more, with a consequent saving in fuel and better make, and at the same time done with an apparatus that is self-acting, contains no valves, and wants no cleaning out.

The difference between the quantity of heat carried into the furnace by the blast at 1300° and that at 1200° is equal to the combustion of about a quarter of a cwt. of coke for each ton of iron made.

In many works three stoves are used per furnace, and in some of the modern works in America and Germany four and even more stoves are sometimes used, and of course a certain amount of equalisation of temperature can be arrived at by changing these stoves at different periods; still it seems that with three stoves and an equaliser better results could be got than with four stoves. This point is mentioned because it has been said that heat would be lost by radiation and conduction from the equaliser; but with three stoves and an equaliser there would be no more loss in this direction than from four stoves.

There seems no doubt that if an even temperature can be maintained, better working of the furnace must be expected.

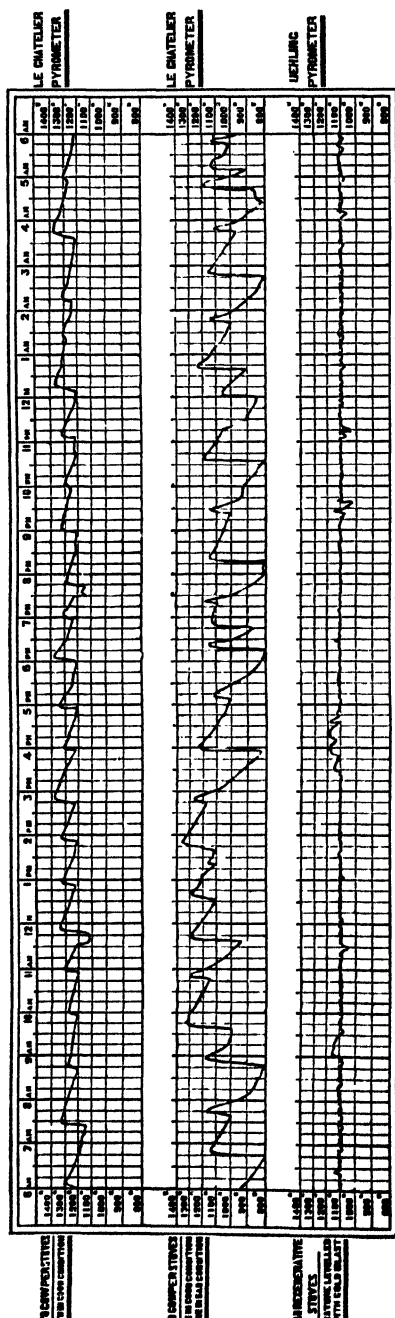
In the days of the cast-iron pipe-stoves, when the temperature was low but regular, there was not nearly as much trouble with furnaces "hanging," and in the few works that have still stuck to the cast-iron pipe-stoves such a thing as a furnace "hanging" is of very rare occurrence.

Now some people who have had trouble with their furnaces since the introduction of the Cowper or regenerative form of

stove have sometimes thought that if they had stuck to the cast-iron pipe-stoves all would have been right, arguing that a little more coke and a little less heat would be cheaper in the long-run if the furnace worked steadily and made a better quality of iron.

But the regenerative stove can be worked at any temperature, and if less heat is wanted it can be got just as well with a regenerative stove as with a cast-iron one. Still the *variation* is there, and is it not this *variation* that is the cause of the trouble?

It has not been proved yet that high heats are worse for the furnace than low. It has often been asserted, but until means have been tried to put a *regular* high heat into a furnace one cannot judge. When working with very high heats it generally means low coke; in other words, maximum heat, minimum coke. If things go wrong, it is the high heat that is blamed. As a rule, the higher the heat the greater the risk



Figs. 3, 4, 5.

of wide variation, showing, therefore, that unless means are employed to equalise the temperature high heats should not be attempted.

In the authors' opinion, the *full* benefit of the hotter blast given by regenerative stoves has not so far been obtained owing to these variations of temperature.

An equaliser is in course of erection at the works of Messrs. The Normanby Ironworks Company, Limited, Middlesbrough, 20 feet diameter by 55 feet high; and as soon as this is in operation, by the kind permission of the owners, results can be laid before the Institute.

The diagrams (Figs. 1 and 2) show the construction of the equaliser. The chequer-work may be of any form, but must be carried on brick arches, as cast-iron grids will not stand the heat.

Fig. 3 is an autographic curve given by a Roberts-Austen recording pyrometer in connection with a Le Chatelier thermocouple fixed on a Cleveland furnace, and shows the working of two stoves, both in good condition.

Fig. 4 is also from a Roberts-Austen recording pyrometer, and shows the working of two stoves on a furnace, one in good condition, and the other in a dirty condition.

Fig. 5 is an enlargement of an autographic record of a Uehling pyrometer (for which the authors are indebted to Mr. Uehling), fixed on an American furnace, from which it will be noticed that the variations of temperature are very small, and also that the temperature is comparatively low.

Figs. 1 and 2 show in plan and sectional elevation how the equaliser can be arranged to take the blast from four stoves to a furnace. This arrangement was got out for a furnace making a very large production, but in most cases three stoves and an equaliser will be all that is required.

An equaliser is just as necessary for a furnace worked by two stoves.

DISCUSSION.

The PRESIDENT said that the question of the measurement of the temperature was a very important one, and one in which he himself took special interest, and the methods of recording temperature which he (the President) had devised was first introduced by Mr. Martin at Dowlais. The meeting would be very glad indeed to hear any one who had anything to say upon the subject.

Mr. WILLIAM HAWDON (Middlesbrough) said he thought the matter that Mr. Harrison had brought before them was a very important one. The Americans, as Mr. Harrison had shown, had already adopted the practice of keeping their temperature level. He believed they had come down to about 1000° or 1100° . There did not appear to him to be any merit in 1100° , and he was of opinion that the higher they could keep their temperatures the more economical they would work. There was no reason why temperatures should not be kept level when they had got them high. Mr. Harrison gained by his apparatus the difference between the minimum and the average, which probably would represent in many cases about a quarter of a hundredweight of coke per ton of iron. That was a most desirable thing. They all knew that irregular working tended to scaffolding in the furnaces, and that was the reason, he imagined, why the Americans had gone down to level working. He thought the step which Mr. Harrison had pointed out was one which was quite in the right direction.

Sir LOWTHIAN BELL, Bart., Past-President, said that those who were accustomed to study the action of blast-furnaces realised that it was an operation which was liable to very great variations in the character of the minerals used—variations it might be in the temperature of the blast, and variations due to the alterations in the hygrometric moisture in the air used. He was not disposed, without further consideration, to attach the great

importance to keeping the heat of a blast at a regular point such as had been claimed for it. He considered that a series of observations should be made with two pyrometers acting simultaneously before finally deciding the question raised by the authors.

Mr. J. H. HARRISON in reply said, that what they had aimed at was getting a regular temperature in the blast in order to bring about a more regular quality of furnace-working, and along with it a more regular quality of iron. What they were all tending to seemed to be greater regularity throughout. Only yesterday they had been told by Sir Lowthian Bell, in a prophecy which he made, that the regularity they had been accustomed to look upon as sufficient for the making of steel rails by the Bessemer process was likely to have to give way to some process that would give a more regular quality of steel than they had hitherto been satisfied with. All that tended in the same direction, namely, to regular working in steel as well as blast-furnaces. It was known that furnaces were worked to-day, and years ago, with the old pipe-stoves where the temperature was low but regular, and that more regular furnace-working was got even with the limited knowledge people had years ago. To-day the furnaces worked with pipe-stoves worked with greater regularity than those worked by regenerative stoves, and it was this fact that had caused them to go into the question of seeing if there were not some means of getting the same regularity of temperature, but at a higher temperature, such as was given by the regenerative stove, and, as mentioned in the paper, they (the authors) thought the full benefit of the regenerative stove (for there was great benefit no doubt to be got from the higher temperature) had not been obtained on account of the irregularities in the temperature between the stoves going on and going off.

The PRESIDENT said, with regard to the pyrometer, it was an instance of the excellent work applied physics could render to metallurgy, and especially to blast-furnace practice. So far as his limited experience had gone, he had never seen such a
1900.—i.

uniform record of the temperature of blast as that given by the authors of the paper.

A hearty vote of thanks having been accorded to Messrs. Lawrence F. Gjers and Joseph H. Harrison for their paper, the following paper by Mr. F. J. R. Carulla was read :—

INGOTS FOR GUN-TUBES AND PROPELLER
SHAFTS.

BY F. J. R. CARULLA, DERBY.

THE form of ingot that would seem to be the most natural for the manufacture of a gun-tube or a propeller shaft is one with a circular section. A round ingot, giving as it does the largest possible mass for the least amount of surface, has attractions which are apt to be misleading. An ingot of this form promises a cleanness of skin in the finished forging unobtainable with another having a larger surface in proportion. Yet owing to the property that steel possesses of expanding as it cools from the molten state, the circular form is the very worst that could be selected to secure soundness. The outside of the ingot is chilled by contact with the mould, and the liquid interior expanding as its temperature falls, may burst the solidified skin, and the ingot turn out of the mould quite useless for the purpose intended.*

F. Gautier seems to refer to this difficulty when describing the attempts of the Swedish artillerymen at Bofors to manufacture steel tube castings for cannon of 12 centimetres bore. He says: "The commencement of this manufacture was beset with difficulties, and success only began when they gave to the iron mould or shell a thickness of 150 millimetres at least. The first four tubes, cast with a shell of only 25 millimetres thick, showed numerous cracks, which made them useless. To avoid this, it was only necessary that the mould in which the casting was made should bear a red heat. It appears that rapidity of cooling plays an important part in the physical structure of the metal."†

Sir William Siemens used at Landore round ingots to roll into tinplate bars, for which a very clean surface is required,

* The specific gravity of liquid "steel" ascertained by Petruscherowsky's method has been found to be 8.06. *Journal of the Iron and Steel Institute*, 1882, p. 793.

† *Journal of the Iron and Steel Institute*, 1881, p. 460.

he reasoning that, as the circle is the figure that embraces the largest area for the same perimeter, such a section would produce the cleanest bars, as the ingots would necessarily have the smallest surface for any given mass of metal. The mathematical reasoning was perfect, but in practice it was found that many of the ingots had longitudinal cracks, owing to the conditions that have been already explained. These cracks were in many instances of no consequence for the purpose to which the steel was put. The ingots could be humoured in the cogging rolls so as to get a very ugly crack to the edge of the bar. There it could do no harm, as the ragged edge of the sheet made from it would be cut off at the shears.

As this metal, although of an ordinary character, was of a soft nature, and therefore interesting in the present connection, and as also no account has been published of the experiments that were made with these round ingots, the following details regarding them may be worth recording:—

Typical Analyses of the Steel Employed.

	A.	B.	C.	D.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon	0·15	0·21	0·18	0·18
Silicon	0·026	...	...	0·037
Sulphur	0·06	0·056	0·063	0·058
Phosphorus	0·035	0·035	0·042	0·045
Manganese	0·48	...	...	0·61

The diameter of the ingots was from $8\frac{1}{2}$ to 9 inches at the top and 7 inches at the bottom. The moulds were of the flower-pot shape, closed at the bottom and provided with trunnions for emptying by turning the mould over. Each ingot weighed about 7 cwt. The result with these small ingots was so unsatisfactory that larger ones were tried, the diameter being increased to 10 inches. This made so great a difference that the small ingots were abandoned, and, as may be seen from the following table, not without good reason:—

Percentage of Good Bars Rolled from Round Ingots.

Date.	Percentage from 8½-inch Ingots.	Percentage from 10-inch Ingots.
1881.		
August 23	61	100
" 24	69	80
" 26	75	100
" 27	89	87
" 29	64	97
" 31	60	85
September 1	67	86
" 2	40	65
" 3	67	88
" 5	54	80
" 6	52	...
" 7	37	53
" 8	50	70
" 9	61	80
" 12	21	74
" 14	38	69
" 15	52	91
" 16	50	96
" 17	54	100
Average	55.9	83.4

It will be seen that the period over which the experiments were carried was sufficiently long to enable one to place reliance on the averages here given. Although obtained nearly nineteen years ago, useful conclusions may still be drawn from these results.

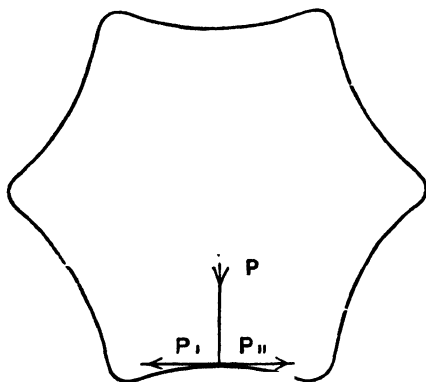
The greater soundness of the larger ingots is probably explained by the cooling of the skin or envelope taking place less suddenly than in the case of the smaller ingot. It may be remembered that A. Pourcel, in his "Notes on the Manufacture of Solid Steel Castings," mentions that Terre-Noire supplied to the French navy a considerable number of hoops for guns of 10 centimetres which were cut out of a round ingot of 385 millimetres diameter, or say 15 inches. There is no mention of cracks having given any trouble.* Nevertheless the expanding interior must produce an undesirable strain on the skin of a round ingot, whatever its size, whether the defect shows itself as an open crack or whether it remains hidden in some less obvious but possibly equally dangerous form.

* *Journal of the Iron and Steel Institute*, 1882, p. 511.

The desirability of starting with a sound ingot when manufacturing important forgings of any kind, but especially those we are considering, will be admitted. The octagonal ingot which Colonel Maitland said was used at Woolwich * must be sounder than a round one. A hexagon ingot would be better, and the square form still more so. Nevertheless, although affording more security from the strains that have been considered, square ingots are also subjected to a pressure from within tending to tear their skin. Although cracks in such

SECTION OF STEEL INGOT

WITH CONCAVE SIDES TO ENSURE SOUNDNESS.



The expansive pressure, P , is largely resolved into tangential pressures, P , P_{II} , compressing the skin of the ingot.

ingots are not the rule, they do occasionally occur, proving the existence of these strains, which the skin cannot always resist.

It may, therefore, be useful to refer to a method which, although already employed, has not been used to the extent that its merit deserves, possibly from the failure to appreciate the harmful effect that has been described when the metal cools, and which is seen in its worst form in the case of the round ingot.

The method that avoids this evil is to give such a section

* *Journal of the Iron and Steel Institute*, 1881, p. 431.

to the ingot that, when the pressure from within occurs, the solidified surface will yield without danger of cracking.

A polygonal ingot with concave sides evidently answers the required conditions. When pressure comes on the face of the ingot from the interior, it is evident that the surface cannot crack. The internal perpendicular pressure on the skin of the ingot is largely resolved into a tangential pressure on the curved or arched sides, and the envelope simply expands, when, if we regard the angles as abutments, we may see that it even undergoes a certain amount of compression. At any rate, that tension so damaging in the circular ingot is evidently completely absent from one of the shape here indicated. (See Section.)

Such a form will have an obvious application for gun-tubes, from which the slightest crack should be absent, but of still far greater value must it be for the manufacture of propeller shafts, on the soundness of which the safety of so many precious living cargoes daily depend. It is quite unnecessary to dwell on a point the importance of which R. A. Hadfield emphasised some time ago before this Institute, and which is so constantly brought prominently before us by the accidents that happen to steamers at sea. So numerous are these becoming as to have led D. B. Morison to condemn ingot steel altogether for the purpose of propeller shafts.*

It is impossible to believe, however, that a material so excellent for all other purposes should not also be preferable for this particular one, if only the soundness of the shaft be assured. Although the chemical composition of the steel and its after treatment in the forge may do much to attain this result, it must never be forgotten that the co-operation of the casting-pit is a condition essential to success.

* *Engineering*, abstracted in the *Journal of the Iron and Steel Institute*, 1894, No. II. p. 446.

DISCUSSION.

Mr. F. RADCLIFFE said that, with reference to the ingot moulds, the author of the paper mentioned the fact of an octagonal mould being used at Woolwich, and also remarked that that form of mould must be sounder than a round one, also that a hexagon ingot would be better, and the square form still more so. At Woolwich a few ingots were cast in an octagonal mould which made the sides concave, but the results obtained did not warrant them in proceeding further with this form of mould. The ingot cast from it weighed about 88 cwts. For the manufacture of forgings for gun-tubes, &c., he was of opinion that the square form of ingot was the most risky one to adopt. This form was suitable for forged trunnion and breech rings only, and no difficulty was experienced in making them comply with the tests demanded in the specification, owing to the fact that when the holes were punched and further enlarged by drifting, the metal was made to flow in a circumferential direction. At Woolwich they got over the difficulties of cracks in the ingots and flaws developing in forging by either lining the moulds with firebricks or steel-moulder's composition, chiefly the latter method, and, in order to make the composition adhere to the mould, projecting buttons were cast inside, which fulfilled the purpose most effectually, three or four casts being made from a 6 or 10-ton mould without necessitating relining. After adopting that kind of mould they never had to replace a mould. The extra cost of lining was covered by saving in the cost of moulds, and also the greater certainty of making successful forgings. No difficulty was experienced in making gun-forgings to stand a soft test with a breaking strength of 30 tons per square inch and 30 per cent. elongation when the test was taken longitudinally, but when the test was taken in a transverse direction the difficulty arose, and unless means were taken to cause the metal to flow in a circumferential direction during the operation of forging, the average elongation of a transverse test would be about half that taken longitudinally. All the forgings consisting of A-tubes, liners, B-tubes, jackets, and trunnions

were now tested in a transverse direction; the position of the testing-pieces had to be so that the middle part of the inner side of each must be a tangent with the bore. To successfully forge these tubes, &c., by means of the ordinary tools used at the steam-hammer was almost impracticable. During the last three years upwards of 3000 gun-forgings had been made in the Gun-factory at Woolwich, and the number of failures to pass the specification was under 3 per cent. This phenomenal success with gun-forgings had been brought about by a combination of circumstances: First, reliable chemical analysis; secondly, having suitable furnaces for heating the ingots and billets, combined with skill and watchfulness throughout the heating operations; and last, but not least, the application of forging tools which had the effect of causing the metal to flow in a circumferential direction in the operation of forging. A full description of these forging tools was given in Patent No. 8709, 1897. All the forgings named were made either from round ingots or round forged billets. The forgings were all forged solid. Mr. Morison was named as having condemned ingot steel altogether for the use of propeller shafts, owing to the numerous accidents to steamers at sea. He (the speaker) thought this was a disquieting reflection upon the reputation of the manufacturers of these shafts, especially when it was so well known what a splendid and reliable material steel could be made to be when all the various operations essential for its manufacture were combined with skill and good judgment. The work done by a piston-rod for a 40-ton hammer would not, he thought, be an unjust comparison with the work of a propeller shaft. After being about seven years at work, the wrought iron piston-rod of their 40-ton hammer at Woolwich became disabled, and it was decided to replace it with one of steel made in the Gun-factory, chiefly because the makers of the hammer did not care to take the risk of supplying one made of steel. The ingot for this was cast, forged, and turned in the Gun-factory at Woolwich. The piston-rod had been almost in constant working for upwards of fourteen years. They had had to replace a broken foundation block and a broken monkey, and to patch up the cast iron hammer legs, yet the piston remained intact. He would give the results of the chemical and mechanical tests:—

	Carbon. Per Cent.	Manganese. Per Cent.	Silicon. Per Cent.
A. Knob end	0·252	0·498	0·021
B. Middle part of rod	0·261	0·512	0·028
C. Inner face of piston-head	0·252	0·498	0·024
D. Outside at largest diameter of piston	0·261	0·505	0·024
E. Centre of piston outside	0·266	0·505	0·019

Mechanical Test.

	Yielding Tons.	Breaking Tons.	Elongation. Per Cent.
Soft or untempered	{ 11·8 13·2	26·4 26·3	33·0 36·0
Oil hardened at 1450°	{ 20·8 20·0	33·0 33·0	30·5 28·5

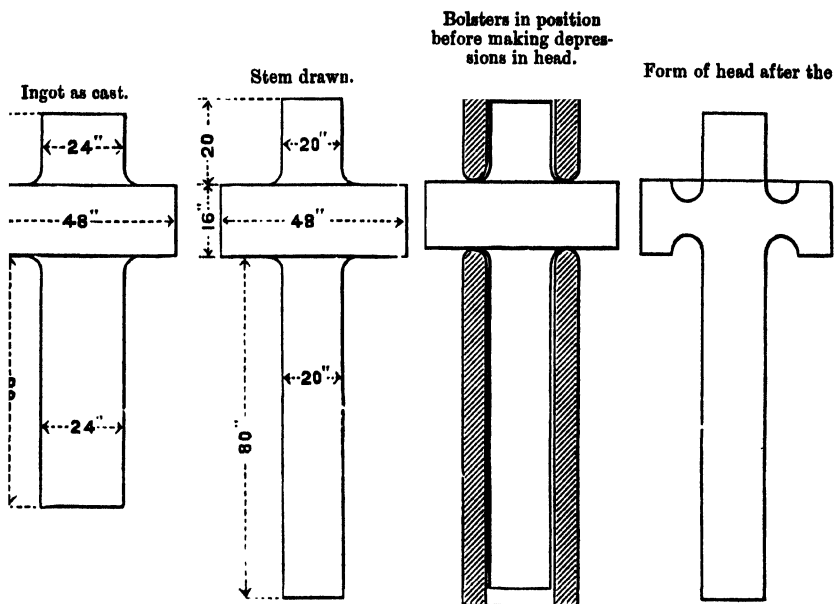
In the mechanical journals reports had been published of breaking piston-rods, and also discussions concerning the most suitable kind of steel to adopt. He ventured to recommend this as a safe sample to imitate for piston-rods of steam-hammers for marine and stationary engine pistons and propeller shafts.

He had been asked by several members about the form of ingot made for the above-named piston-rod, and thought it would not come amiss to append sketches showing the form of ingot cast, and also the various operations in forging, including the finished turned dimensions. He might say that during the forging operations not the slightest crack showed, and when finished turned, not the slightest mark or flaw was visible. It would be seen that with that method of forging pistons the diameters could with safety be indefinitely increased.

CORRESPONDENCE.

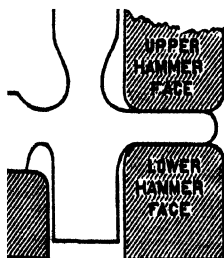
Mr. EMILE DEMENGE (Paris) writes :—

I have read Mr. Carulla's paper with much interest. A clean surface perfectly free from cracks is very desirable for ingots intended to be forged, although such a condition is not an absolute insurance against the possibility of rupture in their manipulation. For unfortunately many other points complicate the solution of the problem, as the present writer has shown when considering the causes of the chief defects found in steel ingots in the articles which appeared in *Le Génie Civil* (vol. xxxii. Nos. 11 and 12).

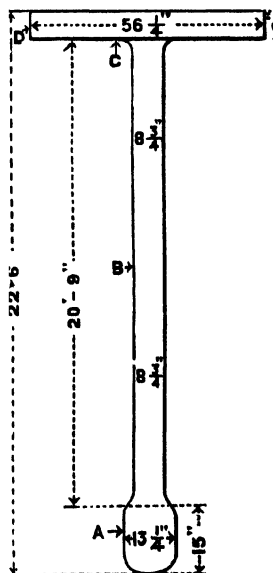


Dimensions of piston (forged).

Head being hammered to
dimensions.



Piston finished (turned).



TEST

Test-piece out from this end.

I wish to make a few remarks regarding the property said to be possessed by steel of dilating when cooling, and during its passage from the liquid to the solid state. It seems to me that liquid steel, far from expanding on cooling, actually suffers a contraction from 1·8 to 2·3 per cent., according to its greater or lesser hardness; that the contraction of very hard steel must approach that of cast iron, which does not exceed 1 per cent., and that this marked difference between well-defined steel—that is to say, iron a little carburetted—and cast iron, which may be considered as steel completely carburetted, comes about because for the last-named alloy *alone* of those we are considering can it be said that there is any expansion at the moment when it passes from the liquid to the solid state. Water, bismuth, copper, silver, and gold also possess this property, but not ordinary steel.

In the present case the mild or medium steel cast in a circular mould cools when it comes in contact with the sides, and a thin skin is rapidly formed surrounding the central mass still in a state of fusion. So soon as this skin begins to contract it becomes detached from the sides of the mould, producing a pressure on the liquid metal which reacts on the solid envelope. The circle being, as is stated, the figure that for a given surface has the least perimeter, the skin of the ingot being unable to enlarge by modifying its shape, gives way, and cracks appear. To avoid this trouble, a shape must be sought that shall give to the horizontal section of the ingot a form that, whilst keeping its symmetry, can undergo modification. This condition is found in a polygonal section, with comparatively short and concave sides, which resist the pressure of the central liquid mass. As a matter of fact, the perimeter being largely increased, the pressure per unit of surface is correspondingly diminished. The skin forms a low circle, well supported by the angles of the ingot, which become solidified almost immediately after casting, and is therefore able to bear successfully the pressures that act against it. As a result, the surface of the ingot is free from longitudinal cracks, which is a great advantage for forging, as it avoids the necessity for scarfing or gouging, *i.e.* the removal of the edges of the cracks in the heated state of the metal by means of a scarfing chisel (gouge). It also prevents much of that reheating which is so detrimental to the quality of the metal. The cooling of the

interior of an ingot having such a form is more regular, and results in a better disposition of the molecules of the steel.

The greater number of the chief French forges have now for more than fifteen years been using ingots of polygonal form with concave sides, and with excellent results. The octagonal section is that generally adopted, the radius of curvature of the sides being equal to that of the circle that circumscribes the polygon. I should say that with the hexagonal section figured in the paper it would be difficult to forge alternately in rectangular planes, a necessary condition to give the piece any regular section. As regards the square section, it presents the disadvantage for large ingots of making the forging less regular, since the draft of the angles is sensibly greater than that of the central part.

In all that precedes I have only considered the case of naked metallic ingot moulds, which are consequently good conductors, and rapidly withdraw a portion of the heat from the molten steel. It is quite another thing with ingot moulds that are lined either with sand composition or firebricks, materials that are bad conductors of heat, and protect the metal of the ingot from all rapid superficial cooling. In these conditions it is quite possible to obtain ingots of circular section perfectly clean on the surface and absolutely free from longitudinal exterior cracks, but such ingots would have what in my opinion is a worse defect, viz., a much deeper central pipe than if cast in unlined metallic moulds. I have myself had occasion to compare two ingots of 20 tons each, cast from exactly the same metal, the first in a cast iron mould, and the second in a mould lined with firebrick. Of the first, about $\frac{7.5}{100}$ of the metal could be used, whilst of the second one, no more than $\frac{4.5}{100}$ could be utilised. The latter, on the other hand, was much cleaner on the surface than the ingot cast in the naked cast iron mould. I would add in conclusion, that there is a means of avoiding in such cases this excessive piping, namely, by compressing the metal immediately after casting, as is done in the Whitworth process, in which moulds of circular section lined with sand composition are used successfully.

Mr. J. G. GORDON (London) writes : The experiments at Landore certainly showed, it appears to me, that the shape of the ingot had a good deal to do with the state of the skin on cooling.

If I recollect right, the late Sir William Siemens expected that the surface of the round tin-bar ingot would chill so rapidly, that if carefully reheated and then cogged, all the cracks would be closed up before coming in contact with air, as he thought, and our roll-turner agreed with him, that the equal pressure of the rolls all round the round ingot would keep the scale on till just as the rolls nipped the ingot.

I do not consider the experiment ever had quite a fair chance, because we had to carry the ingots so far, thus letting them get quite cold before reheating.

Mr. H. E. HEAD (London) writes: I have lost all my notes on the subject of the round ingot experiments at Landore. Having since, however, had occasion to look at the matter from the forge point of view, it strikes me no one has yet been able to set aside the discovery of primitive man, that if you want to draw out a piece of iron you must keep it square. An ingot should therefore be square or rectangular, and the forging should be kept square as long as possible. It is only in this way that you can get the full benefit of the work put into the material, and no shaping of tools will quite make up for any want of squareness. Those considerations apply equally to pressing and rolling as well as hammering, and I can conceive of no process for which a round ingot would be quite suitable, except direct wire drawing.

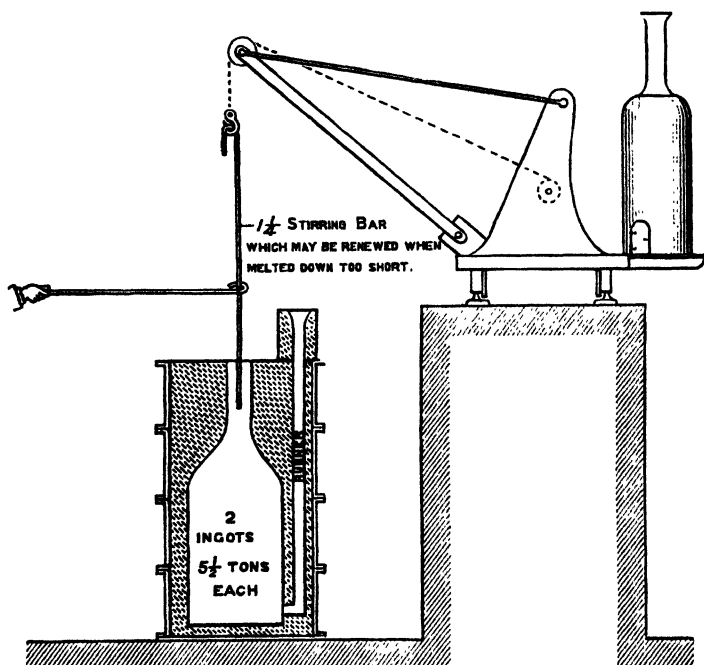
Mr. COSMO JOHNS (Messrs. Vickers, Sons, & Maxim, Ltd., Sheffield) was disposed to question the accuracy of the experiments mentioned on the specific gravity of liquid steel, and the author's deduction that the volume when liquid was smaller than when solid. Many determinations had been made, but all agreed that steel occupied a smaller volume solid than when in the liquid form. Careful experiments were carried out at the River Don Works some time ago by Mr. T. E. Vickers, when it was found that the decrease in volume on solidification was $6\frac{1}{2}$ per cent., while the piping or internal shrinkage cavities represented another $2\frac{1}{2}$ per cent., making a total decrease in volume of 9 per cent. Cracks in ingots were caused, not by the bursting of the shell or walls by the liquid interior expanding as it cooled,

but were due to the ferrostatic pressure of the liquid interior being too great for the newly formed shell. The author's contention that chill moulds of polygonal section with concave or fluted sides were the best was quite correct. Moulds of this form were first introduced at the River Don Works by Mr. T. E. Vickers nearly twenty years ago with marked success.

Mr. J. F. MELLING asked if the author could give any explanation of the longitudinal cracking of octagonal ingots. The crack usually extended the whole length of the ingot down one or more of the angles, and varied in depth from 3 to 5 inches, the size of the ingot being 36 inches extreme diameter and its weight 9 tons. The cracks were invariably oxidised. The ingots were cast in unlined moulds, the sides of the mould merely being washed with compo solution before casting.

Mr. F. J. R. CARULLA replies: Those members of this Institute who have occasion to manufacture large steel ingots will, I feel sure, be grateful to Mr. F. Radcliffe for his eminently practical remarks. The method of holding the fireclay lining by means of projecting buttons, which he has described, must prove a great saving in the cost of moulds, especially as several ingots can be cast without renewing the lining. For large ingots the arrangement seems an ideal one, and the melting-shop manager who adopts it will be relieved of much anxiety, seeing that such moulds can only be destroyed by a rare accident, so that his stock of varying sizes and shapes can be kept up to normal requirements without the fear of running short of some special form at an inopportune moment. This method will, however, labour under the disadvantage pointed out by Mr. Demenge, and it may therefore be of interest to describe a plan to prevent excessive piping, successfully carried out by the late Mr. Scotson, when manager of the melting department at Landore. Mr. Scotson reported to me: "We have cast two large ingots with an arrangement for feeding, as shown on sketch. Also an octagonal ingot for a shaft forging, weighing about six tons. The ingot is first run at the bottom, and filled in the usual manner. The steam-crane, with a suspended stirring bar, is then swung round and lowered into the mould, and a constant stirring is kept up

to prevent the solidification of the top and sides of the feeding head, and to promote the feeding of the body of casting from the metal contained in it. The gases in the metal as they are disengaged escape freely through the fluid head of the casting. When the metal by constant stirring has been fed down into the body of casting for some time, say four or five minutes, the ladle is again brought forward and the feeding head is again filled with hot metal and the stirring repeated. This is done several



times, and repeated as long as the metal remains in a sufficiently liquid condition. It was found possible to keep up the stirring and feeding for more than half-an-hour after the ingots were run. These ingots worked very well under the hammer, and no complaint of hollowness or piping has been made. With a ladle of hot metal for refilling the feeding head, and constant agitation to prevent solidification of the top, I believe it would be possible to cast the heaviest ingots for forging purposes with little or no piping or waste head."

Attention is called by Mr. Gordon to an idea of Sir William Siemens in regard to the round ingot experiments, which may have practical value. It is very probable that the scale may play an important part in the prevention of oxidation of incipient cracks and blowholes close to the surface of the ingot.

It is very interesting to learn through Mr. Cosmo Johns that we owe the introduction of ingots with fluted or arched sides to Mr. T. E. Vickers, of the River Don Works, especially as their use appears to have become very general on the Continent. It seems another instance of an English idea finding favour abroad before being largely adopted in the country of its birth. It is pleasing to have the value of ingots of this section so clearly shown by their adoption, and, as I understand, regular use, by a firm of the reputation of Vickers, Sons, & Maxim, Ltd.

This form of ingot I find, since writing my paper, was not long ago very fully described by Mr. Emile Demenge in the article to which he refers, and which should be read by every steelmaker, entitled "*Les Défauts des Lingots d'Acier.*"* I sincerely thank him for the very complete summary of his views and experience with which he has favoured this discussion.

The view of Mr. Cosmo Johns regarding the specific gravity of liquid steel is supported by Mr. Demenge, who makes a very sweeping assertion and denies that steel has the property of swelling when it cools, ready though he is to admit that cast iron possesses it. Others besides Petruscherosky, however, maintain that steel has this property. We owe to Sir W. Anderson a masterly description of this and allied phenomena,† and Sir Thomas Wrightson has said: "He knew as a matter of fact that steel did float in the way that had been mentioned,"‡ viz., that it is lighter or bulkier at a lower temperature than when molten. The point evidently requires fuller investigation, § still Mr. Demenge's own paper affords evidence going some way

* *Le Génie Civil*, vol. xxxii. p. 182 et seq.

† *Journal of the Iron and Steel Institute*, 1891, No. I. pp. 62-63.

‡ *Ibid.*, 1891, No. I. p. 76.

§ Robert Mallet asserts that the allegation in regard to cast iron that its density when molten is greater than when solid, is wholly erroneous. He admits that cold cast iron floats upon molten cast iron, but maintains that this may be of a less specific gravity than itself. Some other force, Mallet says, the nature of which yet remains to be investigated, keeps it floating.—*Proceedings of the Royal Society*, vol. xxii. (1874) pp. 366-7.

to support this view. He describes * a square ingot with fluted sides used at Creusot—where evidently Mr. Head's theory is in some measure accepted—which when cold becomes nearly a true square. It is clear that an internal pressure is exerted, or the sides would not become flattened. Of course this pressure may be a compound one due to a number of causes, and ferrostatic pressure may be one of them. Nevertheless that ferrostatic pressure cannot be the only one tending to produce cracks is proved by the fact that the small ingots in the Landore experiments gave the worst result. The ferrostatic pressure having lasted the shortest time in these, they should have turned out the best were this pressure the only cause of cracks.

Whatever difference of opinion there may be as to the cause of fracture, it is clear that when it occurs, as in the case mentioned by Mr. Melling, it will necessarily be along the weakest lines or those of least resistance. These in polygonal ingots are along the angles, crystallisation taking place there; hence cracks are likely to be along such lines. The rapidity of teeming will greatly affect the soundness of the finished ingot. Cracks are likely to be present in ingots very rapidly cast, and it may be that the unsatisfactory result obtained at Woolwich with those having curved sides may have been due to this cause. It cannot now be doubted that, whatever may be the true theory of its action, the ingot with fluted or arched sides is a valuable addition to our means of obtaining sound forgings of exceptionally large size.

A vote of thanks to Mr. Carulla having been carried unanimously, the President said, with reference to Mr. Herbert Kilburn Scott's paper on "The Manganese Ores of Brazil," it was a very long one, and they proposed to take it as read. Mr. Scott's brother was present, and he would make a statement regarding it.

* *Le Génie Civil*, vol. xxxii. p. 203.

THE MANGANESE ORES OF BRAZIL.

By HERBERT KILBURN SCOTT.

ALTHOUGH this paper is intended to treat especially of manganese ore deposits and mining, a few preliminary remarks as to the mining and metallurgical industry in the State of Minas Geraes may be interesting.

Mining in the State dates back to the time when the first Portuguese settlers came up from the coast to the interior, and discovered certain gold and diamond placer deposits. The quantity of gold they extracted was enormous, and served to enrich in no small degree the throne of Portugal; a study of old documents treating of the measures taken by the Government to ensure the regular remittance of all the gold to their country being most interesting. Iron ore being plentiful, it happened that simultaneously with the initiation of the mining industry many Catalan forges were now constructed. So important did the mining industry become, that the capital of the State was established in the centre of the then known district, being first named "Villa Rica," afterwards changed to Ouro Preto. Towards the end of the eighteenth century, the alluvial ground began to be worked out, the decline of gold mining set in, and continued until about 1830, when the English revived the industry by introducing machinery and mining in a systematic manner underground. A number of properties were exploited, and two or three are being worked at the present day, notable amongst them being the famous Morro Velho Mine of the St. John del Rey Gold Mining Co., and the Passagem Mine of the Ouro Preto Gold Mining Co.

Certain mining literature written in the early part of this century makes mention of the close proximity of manganese ores to the gold deposits, but it was not until the advent of the locomotive to the district that the working of manganese became possible. On the railway arriving at a place called Itabira in 1890, about 315 miles from Rio, a small charcoal

blast-furnace, "Usina Esperança," was constructed near the line by Mr. Carlos Wigg. He afterwards erected another blast-furnace and engineering workshop at Miguel Burnier, and in 1894 initiated the mining of manganese ore in Brazil.

GENERAL GEOLOGICAL CONSIDERATIONS OF BRAZIL.

Although mining in Brazil practically dates from the discovery of the country by the Portuguese, nothing was placed on record by them of any geological character. Thus it came about that the first studies were carried out by Mawe, an Englishman, and by Von Eschwege, the latter being the first to erect a stamp mill at the Passagem Mine, all work previous to his time being exclusively confined to soft deposits. Von Eschwege's "Pluto Brasiliensis" is a splendid work, and it at once put Brazil ahead of the South American countries with regard to geological study. Other English travellers followed, amongst them Henwood, who was director of the Morro Velho Mine; Gardner, the botanist; and Sir Richard Burton, who wrote somewhat extensively of the gold and diamond mining districts in Minas Geraes in his book "The Highlands of the Brazils." Henwood placed on record most valuable information with regard to the geological features of the gold-bearing strata, and he it was who first referred in detail to the existence of manganese ores.*

In 1865 two American gentlemen, Messrs. Hartt and Derby, commenced the systematic study of the geology of Brazil, and on the unfortunate death of the first named by yellow fever, the work was and is now carried on by Mr. Derby. Owing to the absence of fossils in the rock formations, and other difficulties encountered, the work done by these geologists has not been easy, and Brazil owes to them a great debt, in that they have established the basis for a systematic and detailed examination in the future.

What are known as the Highlands of Brazil, in the regions of Serra do Mar, Mantiqueira, and Espinhaço, were assigned by them to the Laurentian and Huronian periods, on account of the strong resemblance that the rocks of the regions above men-

* In addition to the gold, manganese, and diamonds, other minerals, such as rock crystal, mica, monazite, and topaz, are mined on a more or less extensive scale.

tioned present to those of the typical Laurentian and Huronian of the Canadian lake region and some parts of the United States. In view of recent studies in Canada and the United States and Brazil, Mr. Derby is now inclined to abandon altogether these denominations, and to classify the rocks in question as Archean or Pre-Cambrian, with a reservation as to whether a portion of those of the Serra do Espinhaço (which include the iron and manganese deposits considered in this paper) may not eventually prove to be Cambrian, or even Lower Silurian in age. In these ancient rocks two grand divisions are recognised. The oldest, which is particularly characteristic of the regions of the Serras do Mar and of Mantiqueira, is constituted of various kinds of gneiss, which perhaps more frequently than otherwise are granitoid in texture, and which, with the massive granites and diorites injected into them, give the characteristic topographical features of needles and domes that predominate in these two mountain chains. The second division, predominating in the Serra do Espinhaço, where it produces the characteristic jagged topographical features of monoclinic peaks and ridges, is constituted of a series of schistose quartzites, micaceous schists, and limestones, that has come to be known as the Itacolumite series, from the name given to its quartzitic members. Intermediate in character and position between these two divisions, and perhaps constituting a third division, is a considerable body of true mica schists of doubtful geological relations, since, in appearance at least, they shade off into the true gneisses on the one side and the micaceous schists or phyllites of the Itacolumite series on the other. All of these are more or less abundantly cut by dykes and bosses of granitic, syenitic, dioritic, diabasic, and perhaps other types of eruptive rocks, of which the first three are, in appearance at least, more abundant and characteristic in the first or gneissic division than in the others.

It is, moreover, certain, according to recent but as yet unpublished observations that Mr. O. A. Derby has communicated to the writer, that many of the schistose mountains of both divisions, and particularly of the first, consist of metamorphosed eruptives of various types rather than of sedimentary strata.

For the purpose of the present study of the manganese deposits, the most interesting of the two divisions above men-

tioned is the second or that of the Itacolumite series. The typical member that gives its name to this series is a flaggy micaceous, and in certain conditions and stages of decay, flexible quartzite, well exposed at the base of the Serra do Itacolumi near Ouro Preto, from which the name is derived. This quartzose member passes by a substitution of the mica by micaceous iron oxide to an iron-mica schist or schistose quartzite, which in turn passes to an almost pure iron ore, to which the name of Itabirite was given by Von Eschwege. These iron-bearing beds are known locally as "Jacutinga," a term which will be frequently employed in this paper, since the manganese of the Miguel Burnier district occurs in intimate association with this kind of iron ore.

The denuded outcrops of the Jacutinga * beds are generally covered with a thick sheet of coarse ferruginous conglomerate called "Canga" or Tapanhoacanga (Negro's Head), consisting of broken-up fragments of iron ore which have become re-cemented by limonite. When free from quartz, as it often is, it is an excellent ore, and its enormous development in the Serra do Espinhaço makes this one of the greatest, if not the greatest, iron ore field of the world. The Itacolumite series is the great ore repository of Brazil, and aside from its wealth of iron, as recent developments show, the manganese ore is widespread, and therefore of very great economic importance to the country. It may be interesting to mention that nearly all the gold that has been extracted (up to the discovery of gold in California in 1848 Brazil was the greatest gold-producer in the world) has come from the Itacolumite series. Diamonds are presumed, though not definitely proven, to have come from it originally, and the topaz mines that have been extensively worked in the vicinity of Ouro Preto are in it, and in close proximity to the manganese deposits here considered.

* Jacutinga is the name of a sort of pheasant, and the name was given to the rock on account of a fancied resemblance of the iridescent surface of many of the specimens to the feathers of that bird.

POSITION AND GEOLOGY OF THE MIGUEL BURNIER DEPOSITS.

As will be seen by an examination of the maps accompanying this paper, the manganese deposits stretch along in the direction of Ouro Preto, the outcrops coming out on the summit of the hills around which winds the branch railway line to Ouro Preto. For a distance of about 5 miles from Miguel Burnier in the direction of Ouro Preto, work is being carried on, and also several miles to the south of the above-mentioned place, and in close proximity to the railway there are the Bocaina workings.

Section B.—For the purpose of illustrating the geological information the writer has drawn typical sections (see Figs. A.—F.) taken through Mr. Carlos da Costa Wigg's properties. Of these, perhaps the most uniform is Section B., situated at the working known as Kil. 501, which represents a normal fold, and in which the succession of the rocks from below upwards may be taken as follows:—

- 1st. Micaceous schists.
- 2nd. White limestone.
- 3rd. Impure earthy ores of iron and manganese.
- 4th. Manganese ore.
- 5th. Jacutinga or Itabirite.
- 6th. Grey limestone.
- 7th. Micaceous schists.

We will consider these in the above order:—

(1.) *The Micaceous Schist* is of undetermined and great thickness, and is generally much decomposed. It forms the most important country rock of the district, and when decomposed gives rise to the huge "esbarancados" so common in the vicinity. So far as the writer can see, it has no bearing on the derivation or origin of the deposits of manganese, and for that reason it need not be considered in detail.

(2.) *The White Limestone* is about 10 metres thick, and the analysis of the same as below reveals the presence of a somewhat large quantity of magnesia, the which naturally exists as carbonate. Iron and manganese are also found, and the pre-

sence of the latter element is especially to be noted, as also that the siliceous residue is small.

White Limestone.

Siliceous residue	2.13
Ferric oxide	traces
Ferrous oxide	4.95
Alumina	2.70
Manganous oxide	1.45
Calcium oxide	28.49
Magnesia	19.50

(3.) *The Impure Earthy Ores of Iron and Manganese.* In the mine represented by Section B. a cross-cut was driven from the bed of manganese ore to the white limestone, and as it was thought to have an important bearing on the origin of the manganese bed, the writer has had the various layers having distinctive features analysed as under:—

Analysis.	I.	II.	III.	IV.	V.	VI.
Siliceous residue	14.90	77.60	77.90	77.33	50.80	3.90
Ferric oxide	63.50	7.10	11.50	11.40	17.90	71.50
Alumina	2.20	2.90	3.50	3.40	3.30	2.50
Peroxide of manganese }	7.10	2.10	2.80	6.40	20.00	16.50
Protoxide of manganese }						
Baryta	nil	nil	nil	trace	1.32	2.50

Analysis I.—A dark-coloured strata, two metres thick, next to the limestone. This proved to be an iron ore carrying over 7 per cent. of manganese oxides—a somewhat notable fact, seeing that it is so far from the bed proper.

Analysis II.—A uniform dark red earthy strata, fifteen metres thick. This shows the minimum of manganese oxides, the siliceous residue having increased in inverse ratio to the iron.

Analysis III.—The next four metres of the strata show very little difference from the last, the iron having increased slightly.

Analysis IV.—A darker coloured stuff, two metres thick, which has an increased manganese content and a trace of baryta.

Analysis V.—Black attrition clay, one metre thick. As will be seen, this has quite a large percentage of manganese oxides with some baryta, this latter, by the way, being a common constituent of the manganese ore.

Analysis VI.—Twenty centimetres of micaceous iron ore, lying next to the manganese bed. The analysis shows increased baryta with only a small siliceous residue.

(4.) *The Manganese Ore Bed* varies very much in thickness, being about 3 metres at the point where Section B. was taken. It is made up in great part of hard metallic-looking mineral, which shows bedding, and has interstratified some softer and hydrated ore. The harder ore has a slight tendency to lay in lenticular masses, but occasionally the ore masses itself into very hard irregular blocks. The proportion of the hard ore varies with the situation, but generally averages about 80 per cent. of the whole. The softer ore is very heavily charged with hygroscopic water, and is responsible for the somewhat high percentage of moisture that the Miguel Burnier ores show in the rainy season.

The metallic ore is exceptionally pure, the small quantity of metalloids being mostly concentrated in the softer mineral.

(5.) *The Itabirite or Jacutinga formation* consists of thin (1½ centimetres) layers of fine quartz sand and micaceous iron ore in alternate bands. The thickness of this strata varies between 20 and 40 metres. (See Plate V.) Generally the Itabirite is in a greatly decomposed and non-cohesive state, although sometimes it is exceptionally hard and difficult to work. It is especially notable for its fine folding, but owing to its friability it constitutes a dangerous hanging wall for miners even when dry; in the wet condition it is most difficult to keep up.

(6.) *The Grey Limestone* presents a marked difference in appearance and analysis to that on the foot-wall of the bed, already considered. The strata is about of the same thickness, but it contains a much greater siliceous residue and more iron, and it is probably these that give it the grey appearance. By comparing the analyses, it will be seen that the percentage of manganese is about the same in each case.

Grey Limestone.

Siliceous residue	13·80
Ferrous oxide	5·71
Ferric oxide	5·85
Alumina	0·90
Manganous oxide	1·40
Lime	26·40
Magnesia	13·87

(7.) *The Micaceous Schist* is similar to the one first mentioned.

Section A.—Comparing the other sections with Section B., it will be seen that Section A., situated at Kil. 500, has the position of the bed more or less the same, except for the minor fold, which open working at this point has uncovered. The iron ore conglomerate, $1\frac{1}{2}$ inches thick, is spread all over the hill, and it will be noticed that to the left of the section there is an “esbarancado” or ravine cut in the decomposed micaceous schists by the action of water. It was at the point where this section is taken that the first workings of the manganese ore were commenced, the ore being found in great quantity on the surface, mixed with the superficial red clays. Some thousands of tons have been got, and even at the time of writing this loose boulder ore is not yet worked out. It would appear at first sight as if the boulders were waterworn, but Mr. Derby holds a contrary opinion, as he has seen similar boulders of iron ore at a place called Ipanema that he is convinced were not waterworn.

Section C., Kil. 502, is taken through the highest point of the hill that the bed traverses. The Jacutinga here is exceptionally hard and compact, standing out boldly on a summit that is about 130 metres above the level of the railway. A manganese iron conglomerate exists on the hill to the right, and it may be that the bed is somewhere near, but as yet the writer has not had an opportunity of locating it.

Section D. is taken at the mine known as Kil. 503. It gives the reversal of the fold as compared with Section A., the other wing showing to the right. It may be that at Section C. (Kil. 502) there is something of the kind on the hill to the right.

Section E., Kil. 504.—The strata here has returned to its normal conditions, the bed folding near the surface as in Section A.

Section F., Bocaina.—The strata is at Kil. 503, but the bed is somewhat thinner in places as compared with the rest of the deposits, the limestone faulting into the position that the bed should occupy.

These sections show clearly an intimate association between the manganese ore and the “Jacutinga” and limestone. The entire mass of strata between the two limestone beds is essentially ore, consisting of oxides of iron and manganese mixed with

quartz. These earthy beds are clearly due to the decomposition of some rock from which all but the metallic oxides and free quartz have been leached out, and this could hardly have been other than a carbonate—that is to say, a limestone with a greater or less admixture of iron and manganese carbonates.

The fact that the preserved limestone contains a small proportion of iron and manganese evidently in the state of carbonates, and that its insoluble residue consists exclusively of quartz and pyrites, confirms this hypothesis. The manganese in the bed now being worked is in part friable, like that of the beds between it and the limestone, and in part granular and crystalline.

The iron of the Jacutinga is entirely crystalline, and is certainly not a simple decomposition product of a limestone. If, however, we imagine that by some power the earthy ores should become dehydrated and crystallised, the resulting ore would be Jacutinga, or something very like it, and in the case of beds I. and VI. in Section B., an impure granular manganese ore.

There is nothing very improbable in the hypothesis that these granular ores may also have been originally carbonates that have been decomposed and leached before the metamorphism of the series that transformed the limestone into marble, and in some parts of the district (as alongside the main line just below Miguel Burnier) developed in it a greater or less abundance of specular iron. This specular iron may be presumed to have come from the original siderite.

Although the white limestone is shown in the sections as outcropping, it does not, as a matter of fact, do so, but is represented on the surface by a series of loose masses of rock of a peculiar flaggy appearance, known locally by the name of “Lages,” and considered by prospectors as an indication of the existence of manganese ores near the surface.

This rock analyses as under:—

Silica	36.15
Ferric oxide)	60.85
Ferrous oxide)	
Alumina	0.90
Manganese oxide	0.50
Lime	traces
Magnesia	traces
Baryta	nil
Loss on calcination	4.65

and consists of thin and usually extremely regular alternations of hard black bands of iron oxide, which, in the cases examined, proved to be magnetite rather than hæmatite, with soft yellow ochreous bands and a finely acicular or fibrous structure.

The appearance of this last substance is that of yellow ochre, limonite, or probably xanthosiderite replacing bands of asbestos. In treating some of the harder specimens with acid, there is a considerable residue of well-characterised fibres of asbestos. Besides being found near the manganese bed in the sections, it is also seen in the cutting of the railway where the same passes through the manganese bed. In proof of this hypothesis of the origin of this substance through the replacement by hydrous iron oxide of asbestos, it may be mentioned that Messrs. Derby and Hussak found masses of compact limestone, with layers and bundles of perfectly preserved asbestiform amphibole. These gentlemen inform the writer that the development in the more highly metamorphosed layers of thin limestone, of iron oxides, and lime silicates (amphibole and more rarely garnets) is a common feature throughout the region. As, for example, near the station of Rodrigo Silva, where the rock is charged with beautiful clusters of green actinolite.

Whatever may have been the original state of the manganese ore bed, there can be no doubt that in its present condition, and down to the level to which it has been worked, it is a residual deposit from which the other elements have been leached out. From this point of view the question as to what depth the leaching and decomposition has taken place becomes of considerable economic importance. As far as can be judged from the exploratory work which the writer has carried out, the ore bed presents every indication of continuing indefinitely in depth, in which case the limit of mining operations, if not fixed by a change in the character of the ore, will depend entirely on economic conditions.

The present workings have reached a depth of 150 metres from the surface outcrop of the bed, and thus far has not revealed any indication of material change in the character of the manganese ore.

It may perhaps be assumed that such change, when it occurs, will be at or near the present drainage level of the adjacent valley, the stream of which is some 300 metres lower than the

lowest point reached in the mine. If, as seems to be the case with the earthy beds between the ore bed and the limestone, the decomposition and leaching of the ore bed has been a modern process, a relation between it and the present system of superficial drainage may be predicted, though exactly what its nature will be, or at what point in the sloping side of the valley the change will be found, can only be a matter of conjecture. If, on the other hand (as in the case with the Jacutinga bed), the leaching was an ancient process, it must have been entirely independent of the present drainage conditions, and in this case it may reasonably be assumed that no material change will be found in the character of the ore at very deep levels.

HISTORY OF MANGANESE MINING.

The presence of manganese ore near Miguel Burnier was first noted during the construction of the branch line of the Central Railway to Ouro Preto by Mr. Henry Hargreaves, the chief engineer. He discovered a bed of it crossing a cutting just beyond Miguel Burnier, and sent a sample of it for analysis to Dr. Domingo Rocha, Professor of the School of Mines at Ouro Preto. This was in the year 1888, but the exchange at that time being high, it precluded any possibility of the ore being worked with advantage. In 1893, however, Mr. Carlos da Costa Wigg had his attention called to the manganese deposits, and the exchange rate being more favourable, he acquired the necessary land, and having obtained from the Government special freight rates, began mining the ore in 1894, under the name of Costa & Almeida or Usina Wigg.

In 1897 another firm, Messrs. Airosa & Co., commenced work in the neighbourhood, and the total quantities of ore exported to the end of this year have been as follows:—

Year.	Usina Wigg. Miguel Burnier.	Airosa & Co. Miguel Burnier.	Pedras Pretas Co. Bahia.	Belgian Co. Miguel Burnier.
1894	1,430	...	...	...
1895	5,570	...	...	...
1896	14,710	...	...	...
1897	8,970	5,400	...	...
1898	15,610	11,500	...	...
1899	28,400	34,000	4,992	1,000

The ore has been exported to the United States and England, by far the greater part having been taken by Messrs. Carnegie & Co. of Pittsburg, and Messrs. Bolckow, Vaughan & Co., Middlesbrough.

DESCRIPTION OF THE USINA WIGG AND ITS MANGANESE MINES.

The properties of this firm consist of a blast-furnace, foundry, and engineering works, as well as about 6000 acres of mineral lands, containing the most improved manganese deposits of the district, also abundant fuel, water-power, &c. The principal ore deposit of the firm extends from Kil. 500 to Kil. 503 on the branch line of the railway to Ouro Preto, other deposits being worked at Kil. 504 on the same line, and at Bocaina on the Central line, just south of Miguel Burnier. The bed outcrops almost uninterruptedly all along the hill, which varies in height between 80 and 150 metres above the level of the railway. At the commencement of the exploitation the whole of the output was got by open-cast working, the bed being found uncovered, or with such a small quantity of over-burden that it could be very cheaply extracted; the hillside being taken advantage of for the waste heaps. (See Plate VI.)

After a time this open-cast became impracticable, especially in the rainy season, so underground work was commenced. Levels were driven into the bed at about 30 metres, vertical height between each, and of three sections as under—

						Height.	Width.
No. 1	.	.	.	.	.	1'60	× 1'20 metre
No. 2	.	.	.	.	.	2'00	✓ 1'50 "
No. 3	.	.	.	.	.	2'00	× 2'00 "

The smallest size is used for the exploratory headings, which are continually found necessary in order to follow the direction of the bed as it curves about. The width of 1'20 metres just allows of the passage of a small trolley on a 50-centimetre gauge line. The wood used for the sets in this smallest level need not be of good quality, and consequently rejected railway sleepers or other lumber is used, and common 1-inch boards for lining up. As all these levels are afterwards substituted, the sets are used over and over again.

No. 2 size is used for less important permanent levels, and will allow of a single trolley line, and also space for passage of the workmen.

The No. 3, or largest size, is used for the main levels, and is arranged to allow two lines of 20-inch gauge to be laid.

The two smaller levels are always driven in ore, but the largest, owing to the great width of the panel, occasionally requires some country rock to be got. It is preferably taken from the foot-wall, as the hanging wall is dangerous, and especially so when of friable Jacutinga. The timber used for the sets of the two larger sized levels is of native quality, the most durable and suitable wood for this work being "Candeia," found in the high lands about Burnier. It has a very strong and somewhat disagreeable odour, which probably accounts for its being so durable, by keeping the insects from attacking it. Unfortunately the quantity available is limited, the trees not growing in quantity or to great thickness, so that other kinds of wood, such as Angelim, Aroeira, Brauna, Sucopira, Ipe-Jacaranda, have to be used for lining up the sets. These woods are brought from the interior by rail.

At intervals of 40 metres, rises are put up from one level to the other. In driving them, the miner keeps close to the foot-wall, working as narrowly as possible, and after he has cut through into the next level, the rise is widened out and timbered. A piece of the bed about 4 metres in height is left immediately over the main levels, and the stoping is commenced from the top of it upwards towards the next level. (Plate XIV.)

Every rise is furnished with a bin or pocket, which is constructed alongside the main road and has a capacity for about 20 tons of ore. It is provided with a suitable door to enable the ore trollies to be filled with regularity, a pass for the workmen and material being kept on the side of the bin. The side of the rises is 2.00 metres by 2.00 metres, and the same kind of timber is used in them as in the main levels. In the majority of cases the bed is inclined at from 40° to 60°, so that ordinary timbering is quite sufficient. Occasionally, however, the bed is vertical, and then it is necessary to vary the method. Iron shoots are placed in the

rises, and serve to bring down the ore from the stopes to the bins. They are in 1 and 2 metre lengths, and can be easily fastened together.

In order to avoid any possibility of falls, the hanging wall, a thickness of 50 centimetres of the ore bed, is left over the cap-piece of the rise timbering.

The stoping is commenced by putting in a small road on each side of the rise to meet similar ones from the other rises. These roads are of the smallest size, 1·60 metre by 1·20 metre, and the sets are put in about 2 metres apart, the cap-pieces only being lined to prevent small falls. To facilitate the extraction of the ore, the small headings are driven in on the foot-wall side of the bed, and a little of the foot-wall is mined, thus releasing the bed, and enabling the miner to get the ore with greater facility. The roads from each rise meet about half way, each miner working back, taking out the rest of the bed on the hanging wall side and filling up the stopes as he proceeds. The filling is obtained from between the bed and the white limestone by driving in cross-cuts of small section at right angles to the bed.

As falls occurred when the timber was taken out during the filling of the stope, it has now been decided to leave the timber *in situ*, and as a recompense for the loss of the wood, there is the greater security of the mine, and consequent greater efficiency of the miners. It has been found that the hanging wall is perfectly secure so long as the bed is not allowed to come away, so that the narrow timbering put in is enough to enable all the bed to be got and filled in without any danger to the men. After one piece of 1·60 metre high has been got, another one is started immediately above it, and the filling being soft, the set nearest the hanging wall is allowed to rest on the cap-piece of the set below. The ore is thrown into the shoots from the bed without any picking, this not being necessary. Up to the present time all the levels are dry, no water in any quantity being found in the present workings owing to their altitude.

The ore from the mine pockets is loaded into trollies, and by mule traction is run to the inclined planes for transmission to the storage platforms on the side of the railway. It is all

shipped as mined, with the exception of some from one of the top levels that is passed over a grizzly at the bottom of a long iron shoot.

The most important loading platform is on the siding at Kil. 501 (Plates VII. and VIIIA.), to which the ore is served by a self-acting gravity incline of 500 metres in length with trollies of 2 tons capacity, each emptying their contents directly into the railway cars, or, if they are not available, on to the storage platform, which has a capacity of 3000 tons. The siding platform will take a train of thirteen railway cars, and it is contemplated extending the same and the construction of loading bins for a total capacity of 500 tons to serve a level that is just being opened up. At Kil. 500 there are eight bins of 12 tons each (or one railway car capacity), which load directly into the railway cars. (Plate VA.) At Kil. 503 ore bins are being erected with a capacity of 500 tons, to take the ore from an inclined plane that serves the top levels of the Ouro Preto side of the hill. At Kil. 502 and Kil. 504 there are other loading platforms of secondary importance.

The workmen employed are Brazilians, Italians, and Spaniards. The former, though good workmen, keep somewhat irregular time, owing to their homes being in the surrounding villages, to which they are continually going for a holiday. The Italians and Spaniards being foreigners, work with regularity, and so are more reliable. The working day is divided into two shifts of twelve hours, with one hour in each shift for meals. The climate is exceptionally good, the mines being situated 4000 feet above the level of the sea.

The handling of the ore from the mouth of the different levels to the platform is done at a fixed price per ton, but the getting of the ore has not yet been put on a piece-work basis owing to the difficulty of fixing a uniform price. As a substitute for piecework the leading miners are paid a bonus over and above their wages, the bonus being fixed at the conclusion of each length of stoping or driving. The miners earn $4\frac{1}{2}$ milreis per day, and the other hands $3\frac{1}{2}$ milreis, these latter only working ten hours per day.

The blast-furnace pipe-stove foundry (two cupolas), mechanics' shop, laboratory, offices, &c., are situated near the railway station, 1900.—i.

Miguel Burnier. Power for the tools, &c., is generated by a Pelton wheel, and the whole of the repair work, &c., for the mines is done in the works, which are thus of great value.

The laboratory is equipped with the best apparatus and chemicals, and was constructed immediately mining operations were commenced. Although, as will be seen by the analyses, the ores are of exceptional purity, still great care is always taken to prevent any possibility of the percentage of the manganese in the cargoes being lowered by admixture with poor ores or careless mining, and allowing small portions of Jacutinga to be mixed with the ore. A monthly examination of all the workings is made, and such examination has served to keep check on careless work, samples being taken on each occasion and analysed without delay. The naked eye is not sufficient to detect intermixture with iron ores. In addition to being used for checking mining work, the laboratory has been of infinite value for assaying samples from other deposits that have been discovered from time to time.

The analytical method generally used at the mines is Pattison's volumetric, this having been found to be sufficiently accurate and quick, but for special work Blair's phosphate method is sometimes used. Although there is much divergence of opinion as to the best way of estimating manganese, it has been found that with the Miguel Burnier ore the results obtained by the volumetric method above referred to agree remarkably well with those of one of the leading chemists in the United States, who weighs the manganese as phosphate. The extreme purity of the ore, more especially the absence of lime, causes a general agreement of Miguel Burnier cargoes, as is shown by frequent analyses by three different chemists, each using a different method. In none of the Brazilian ores has any manganese been found in the residue after dissolving in hydrochloric acid.

In the Pequiry and Lafayette ores a varying quantity up to 7 per cent. of carbonaceous matter, mostly graphite, has shown up, a circumstance which is very deceiving in the field, many highly siliceous ores giving a black streak.

In order to profit as much as possible by the analytical work, pieces of each distinctive class of ore are kept in stoppered bottles, and the collection of these serves as a guide in determin-

ing the value of new ores brought in, and teaching the foremen miners to recognise inferior classes of ore, as well as aid them in "picking" when it is found necessary. In addition to the checking of the quality of the ore by analytical work, means have been taken to increase the percentage of metallic manganese in any ore that has been got carelessly, by riddling, the swinging suspended riddle being used.

On examination of the two complete analyses of cargo samples (see Table), it will be seen that they show the manganese at over 55 per cent., with phosphorus at 0.030 and 0.021. The first was shipped by the Usina Wigg at the commencement of the exploration and the second last year, thus showing the remarkable regularity of the ore.

The curves of phosphorus, silica, manganese, and moisture given in Plate XIII. show great regularity in same, that of phosphorus being especially noticeable. The numbering refers to cargoes. The moisture has at times been exceptionally high, but in the future, with better means of transport, it will not be exposed so long to the rain in the wet season.

The amount of ore available on the present Usina Wigg properties is somewhat difficult of estimation, but the writer would put a very conservative estimate in sight and easy of extraction without motive power, at 2,000,000 tons.

The firm of Airosa & Co. work deposits of ore on the branch line to Ouro Preto at Kil. 498, 499, and 504, as well as at other places of secondary importance, also at Pequiry, which will be referred to later. In 1895 this company leased the right to mine in these lands from a rural proprietor, Mr. T. A. Goes, the royalty being fixed at 4d. per ton (500 reis).

They work the ore both by underground and open-cast, and have a number of platforms along the line for storing the mineral, as well as inclined planes for the transport of the ore.

The analyses of cargoes of ore shipped give an average of about 50 per cent. metallic manganese dried at 212° F., with .04 per cent. of phosphorus, and moisture varying between 10 and 20 per cent.

RAILWAY AND OCEAN TRANSPORT.

It is a fortunate thing that the manganese ore bed of Miguel Burnier should be situated so near the Central Railway of Brazil. This line serves the States of Sao Paulo and Minas Geraes, and passes right through the mining zone of Minas, to which, before the time of the railway, the transport of machinery was well-nigh impossible. At present the line is about 800 kilometres long, but it is intended to prolong it to a point where the Rio Sao Francisco becomes navigable.

Up to Lafayette, 450 kilometres from Rio, the line is wide gauge, and from this point onwards it is metre gauge. Formerly the tonnage for the interior considerably exceeded that carried on the return journey, but the initiation of manganese mining changed that, for after taking the various points into consideration, the Government, in 1894, granted to Mr. Wigg a special tariff of about 5 milreis (3s. 8d.) per ton for ore carried to Rio. Unfortunately exaggerated accounts as to the profits derived from the industry caused the Government to increase the tariff several times, till finally it arrived at 14 milreis (about 9s. 4d.), an increase of nearly 200 per cent. In addition to this abnormally high tariff, the railway authorities did not furnish sufficient waggons for the transport of the ore excavated, and consequently the exploitation of the mines was hindered. When the present heads of the Government, Federal as well as State—Drs. Campos Salles and Silviano Brandao—entered office, they were animated with better intentions towards the mining industry generally, and especially manganese mining (it is to be hoped that the increased interest which the Government are taking in mining may be perpetuated in successive Governments), and on the recommendation of Dr. Alfredo Maia, the director of the Central Railway, the tariff has been reduced to 8·8 milreis (about 5s.); he has also organised the transport of the ore on much more liberal lines than was formerly the case.

The service is effected by special mineral trains, which take the ore direct to Rio after transshipment at Lafayette. On arrival in Rio, the ore is loaded into hulks alongside the railway pier, and is there stored until it can be shipped, or else it is unloaded on an island in the Bay. Freights to England are very irregular, varying between 10s. and 20s.

DEPOSITS IN THE LAFAYETTE DISTRICT.

Lafayette District.—Since exploratory work was commenced in the vicinity of Miguel Burnier, and more especially since 1895, many deposits of manganese ore have been discovered. The great majority have, however, proved to be valueless from a commercial point of view, some owing to being phosphoric, and others siliceous, and not a few because of their being caps merely, and not bedded deposits. The country round Lafayette is of altogether a different character, physically and geologically, to that of the Miguel Burnier and Ouro Preto district, the predominating rocks being granite and mica schists, with complete absence of Jacutinga, or other iron ore, and limestones. Whilst in the Miguel Burnier vicinity the country is extremely rugged, in the Lafayette district it is only slightly undulating, with few eminences.

BARROSA.—In the early part of 1896 the firm of Nascimento & Gerspacher commenced work on an outcrop of manganese at a point on the Central Railway of Brazil called Barrosa, between the stations of Lafayette and Buarque de Macedo, on the broad-gauge line, and 45 kilometres nearer Rio than Miguel Burnier.

At the outcropping of the Barrosa deposit, as at most of the others, there was found a large quantity of broken ore, lying horizontally and paving the summit of the hill, which is about 80 metres above the level of the Central Railway line. The bed was found to be 4 metres thick with a trend of N. and S. and dip of 80 degrees.

The ore has a black manganiferous appearance, and analyses showed that this was due to the quantity of carbonaceous matter contained. A sample carefully taken gave results as per analysis No. 1, and of an average as per analysis No. 2.

The utter worthlessness of the property from a commercial point of view must have been evident to the explorers from the beginning, but they continued to work for some time, and equipped the property with inclined plane, siding on the railway, &c. Some two or three thousand tons were shipped to Rio, but the financial results not being satisfactory, work was gradually suspended and the place abandoned. The ore was evidently a

Braunite as shown by the large quantity of MnO and free silicon present, this latter being masked by the carbonaceous matter in the ore.

In the vicinity of this property some other outcrops of almost identically the same quality are seen, but after examination, none of them have been found to have any commercial value.

At the beginning of 1897 attention was beginning to be called to other deposits of manganese ore in the vicinity of Lafayette, notably at Morro da Mina, Pequiry, Sao Gonçalo, &c.

MORRO DA MINA.—Morro da Mina, about two miles to the east of the Central Railway in the direction of Ouro Preto, is so called owing to gold having at one time been worked there. The Morro hill is a conical eminence, and on the summit there is found a highly siliceous manganese ore. The hill is no doubt traversed by a thick bed of low grade manganese ore, and the cap is the result of the breaking down of an exposed outcrop of the bed, the which has been cemented together into a brecciform mass by the hydrated oxides and clayey matter, somewhat in the same manner as the "Caniga," which is formed by the breaking down of the Jacutinga. This brecciform mass extends over the whole summit of the mountain, and occasionally, owing to weathering, some good samples of ore can be found, but, as already explained, the stuff is very highly silicated. The property was bought by an Italian in 1896, but although he has made many efforts to prove its commercial value, up to the present he has not succeeded.

The analysis of the ore No. 3 shows it to be of the same character as that at Barrosa, already referred to, except that, in addition to being low in manganese and high in silica, it has also an abnormal quantity of phosphorus. In the vicinity of this property are outcrops of manganese ore all more or less silicated, and giving results in metallic manganese between 20 and 35 per cent.

PEQUIRY.—The Pequiry property is situated about eight miles from Lafayette, on the opposite or west side of the line to Morra da Mina. The outcrop here has a very good metallic appearance, showing up uniformly well on the short extent of outcrop visible. The property has not been opened up owing

to the known irregular character of the Lafayette deposits, but in order if possible to discover the commercial value of the property, a series of analyses were made by the writer of pieces of the ore body, and these gave as an average 46·40 per cent. of metallic manganese, the results varying between 30 and 50 per cent. The outcrop showing on the other side of the hill in the direction of the strike gave only 18·70 per cent. of manganese, being very siliceous.

The right to explore manganese in this property was acquired by Messrs. Nascimento & Gerspacher in 1897, contracting to pay a royalty of 1·1 milreis (9d.) per ton, and this right was afterwards passed to the Airosa Company, who have laid down a narrow-gauge line to the station of Gaya, on the Central Railway, between Lafayette and Soledade. Gaya is distant about 12 to 14 kilometres, and at the time of writing this ore is being transported on a small scale. A sample of the loose weathered ore at present being exported gave a somewhat higher percentage of manganese (Analysis No. 4) than the average of samples tested from the outcrop already referred to; but this is only natural in weathered ore. The phosphorus content causes the same to be classed as a second class mineral, running as it does to over 0·1 per cent.

It will be interesting to see the financial result of the venture, taking into consideration the increased cost of putting the same on the Central Railway, the high percentage of silica and phosphorus as compared with other ore shipped, and the probability of the good, or rather less siliceous ore degenerating into the average Lafayette district braunite in the future.

SAO GONÇALO.—The Sao Gonçalo property is about 6 kilometres from Pequiry and 10 from Lafayette, and from the direction of the strike, situation of ore, appearance, &c., it apparently belongs to the same bed as that of Pequiry. The outcrop stands out boldly in the slope of the valley, and shows the bed to be about 8 metres thick, the strike being S.W.—N.E. and dip 45°.

Examining the outcrop for a little distance, the ore is very good-looking stuff, but further it is found mixed up with the country rock, and this latter analysed very low in manganese. The ore is extremely hard, and although this would to some

extent increase cost of cutting, the absence of moisture in the ore would neutralise that. No exploratory work is being done now, so that no very good idea can be gained as to its commercial value. The property is owned by a Belgian company, and they have projected a narrow metre-gauge railway to Lafayette, where the ore can be taken direct onto the wide gauge of the Central line.

A number of analyses of pieces of ore taken from the workings gave results varying between 28 and 54 per cent., and an average sample taken from the outcrop gave Analysis No. 5, which will be noted as being very similar to the Pequiry analysis.

In the direction of Burnier upon both sides of the Central Railway there are outcrops of manganese ore, but all are very impure, being so silicated as to be considered a mangiferous ore.

GENERAL CONSIDERATIONS.—The manganese outcrops in the Lafayette district are contemporaneous deposits, and, as can be seen from analytical results, the manganese contents vary considerably. The absence of Jacutinga and the intermixture of so much fine silica in their composition would point to their being of a different derivation to the deposits in or round Miguel Burnier.

The Lafayette district is made up geologically of clays formed by the decomposition of granites and schists and undecomposed granite, and it is probable that the ore beds have been formed by the leaching out of the manganese from some siliceous rock like granite; the separation of manganese and silica, which occurs in the amorphous state, being, for some reason or other, contemporaneous. Baryta, which shows up so strongly occasionally round Burnier, is almost entirely absent here.

DEPOSITS BETWEEN BURNIER AND OURO PRETO.

The Jacutinga iron schist strata continues to outcrop irregularly all along both sides of the railway on the branch line towards Ouro Preto, the same following the dip of the mountain, and it is in the vicinity of this that the manganese masses are found.

The manganese occurs in two distinct states :—

1st. Crystallised.—This ore, although not occurring generally with the Jacutinga, may be considered as derived from the denudation of the manganese bed that accompanies the Jacutinga, with subsequent re-crystallisation in the superficial clays. It is very rich in peroxide, but has often a reduced commercial value owing to its high iron, silica and phosphorus contents.

As yet it has not been found in any well-defined beds, restricting itself to comparatively small quantities over a large area. At grass it has a good appearance, owing to its interstices having been deprived by the weather of their earthy contents, but immediately below the surface it is generally found impure, and degenerates into a simple brecciform mass bound with limonite.

It is rather difficult to explain its high phosphorus contents, except it be that, being invariably superficial, it has taken up some phosphates, as often occurs with limonite.

2nd. Hydrated Ores.—Manganese ores are often found acting as the binding material in conglomerate masses of broken-down Jacutinga. Surface stuff, as in the crystallised ore, is good, but below it is siliceous in the highest degree. This hydrated ore often contains in varying quantities nickel and cobalt, the which gives it a green appearance. These ores are the most modern, and are being formed at the present time by depositions from solutions coming from the manganese beds.

Properties showing both qualities of ore have been exploited from time to time.

The Rodeio property is situated in a valley between the branch line to Ouro Preto and the Ouro Branco mountain, and here detached masses of the crystallised ore are found. When first discovered, this ore attracted a good deal of attention, but a little exploratory work was sufficient to show that there was no great quantity of good ore available. The analysis revealed the presence of high phosphorus (Analysis No. 6).

From this property onwards numerous outcrops of ore are to be found, as at the "Capão" property. Here some work has been done on a cap of the hydrated ore (Analysis No. 7), but it would appear that the explorers have already got through the cap, and there is no continuity in depth.

Further in the direction of Ouro Preto, near the Rodrigo Silva Station, a small quantity of ore has been worked. The ore is of the crystallised character, occurring in pockets in the whitish clay, but it is already almost worked out (Analysis No. 8).

Onwards from Rodrigo Silva manganese ores are widely disseminated.

At Saramenha, crystallised ore is found (Analysis No. 9). This property has been acquired by a Belgian company. A sample of the ore as exported gave Analysis No. 10.

Near Miguel Burnier, but a little to the south, at a place called Bocaina, in the vicinity of the deposit already described, a firm began in 1898 to explore manganese ore at several points about 2 kilometres from the Central Railway. A small quantity of ore was exported, but the high percentage of iron and phosphorus reduced its value to such an extent as to cause the company to go into liquidation.

The ore mass to which Analysis No. 12 refers was made up of crystallised ore held together by limonite and showing a beautifully iridescent surface. There being no appearance of continuity in the mass, it may be taken as being the result of the denudation of the bed of manganese higher up the mountain. As a matter of fact, there is a deposit higher up the mountain that tends to be uniform, but even this is not intercalated between well-defined country rocks, but found in a yellow clay, produced no doubt by the decomposition of some schist. Work was carried on at this point for some time, a large amount of ore being found, as a sort of wad, giving Analysis No. 11. It was exceedingly porous, and contained about 50 per cent. of hygroscopic water.

At the Vigia, and other properties round Burnier, a little exploratory work has been done, the deposits being of a nodular nature enclosed in a conglomerate containing much Jacutinga, debrite, and free silica, as far as can be seen useless from a commercial point of view (Analysis No. 13).

At several places, notably above the Burnier railway tunnel, three veins of manganese have been found that showed the presence of nickel and cobalt, one analysis giving a fair quantity of the metal (Analysis No. 14). These veins are of the same

character as the hydrated caps already referred to, and run irregularly through the superficial clay.

About Renera and Gandarella, beyond Ouro Preto, deposits of very fine crystalline manganese are said to exist, but the writer has no reliable information about them.

Near the station of Ressaquimba on the Central Railway a large manganiferous iron ore deposit is found in quantity (Analysis No. 16), and at Ilhéos, on the Qeste de Minas Railway line, smaller pieces of manganese ore have been found (Analysis No. 16).

OTHER BRAZILIAN DEPOSITS.

Beyond the limits of the State of Minas Geraes, deposits of manganese ores are quite common, but in many cases, indeed in the great majority of cases, there are difficulties of transport.

Near Bahia, at Nazareth, exploratory work has been going on by a Brazilian firm, and they exported, in 1899, 4992 tons of ore. The results of the analyses of their cargoes are satisfactory. Professor Branner of Stanford University, U.S.A., has recently written a paper on these deposits.

In the States of Santa Catherina, Parana, and Matto Grosso, manganese properties exist, but they have not as yet any commercial value.

THE WORLD'S MANGANESE DEPOSITS AND THE FUTURE OF BRAZILIAN MANGANESE.

In 1895 the world's production of manganese ore was about 140,000 tons, whilst the year 1899 was the highest on record, probably 800,000 tons, divided as follows:—

Turkey and Greece	54,000
Japan	5,000
Russia	369,000
Spain and Portugal	140,000
India	77,000
Chili	37,000
Brazil	62,000
Cuba	15,000
France	28,000
Other countries	10,000
	<hr/>
	800,000

The consumption in Europe is about 600,000 tons, and in the United States 200,000 tons.

Owing to the necessity of having ore as low as possible in phosphorus (the more so as low phosphoric iron ores are getting more difficult to obtain), the percentage of phosphorus practically regulates the grading of the ore. The different qualities, classified according to their phosphorus contents, are as follows:—

Low Phosphorus Ores.—Brazil, Chili, France, Turkey, Cuba, Japan.

Phosphoric Ores.—Caucasus, India, Greece.

Mineral from Spain and Portugal is not employed for the manufacture of ferrous manganese, but for the basic Bessemer process, and the elimination of sulphur in pyritic iron ore.

Average Analysis of Manganese as per MESSRS. MACQUEEN BROS.,
London.

	Cargo Samples.													
	Caucasus.	Greece.		Turkey.		Spain.		India.		Chili.		Cuba.	France.	
Net manganese	51	52	45	43	53	43	33	48	46	49	52	47	52	43
Net iron	1	1	1	3	1	4	7	6	11	0	1	2	0	0
Siliceous residue	8	8	12	12	9	10	13	3	3	5	9	6	6	7
Phosphorus	17	09	10	015	08	03	03	13	28	015	08	073	05	05

Analyses of Two Cargoes of Usina Wigg Ore, by MR. E. RILEY, London.

	Feb. 1895, ex "Chirasmore."	March 1899, ex "Virginia."
Silica	0.53	1.27
Manganese peroxide	80.62	79.40
Manganese protoxide	5.47	6.23
Alumina	2.21	1.45
Oxide of iron	2.50	4.03
Baryta	2.30	1.90
Lime	0.70	traces
Magnesia	1.05	0.05
Phosphoric acid	0.07	0.048
Sulphuric acid	traces	0.065
Arsenic acid	nil	0.034
Carbonic acid	nil	nil
Potash and soda	traces	0.55
Combined water	4.95	4.74
	100.30	99.757
Manganese per cent.	55.14	55.02
Phosphorus per cent.	0.030	0.021

An examination of the analyses, Nos. 8, 9, and 10, given in the Table on p. 196, serves to show that the manganese ore shipped by the Usina Wigg is far and away the best.

The writer has little information about the Turkish ore, but he believes that the production is limited.

Since the conclusion of the war with Spain, Cuba has begun to ship again, but the deposits are somewhat irregular.

India came into the market a few years ago, and sends a comparatively large quantity, all of it high in phosphorus, and available only for the basic process.

The French ore is a carbonate low in phosphorus and consequently first class.








Of Japanese ore there is no information available, except that there is no probability of large shipments, as the deposits are of small extent.

From the Caucasus comes the greater part of the world's production. In 1885, 40,000 tons were shipped, and now the annual production is 350,000 to 400,000 tons. Mr. Frank Drake, who wrote a paper on the manganese industry of the Caucasus, says that the ore available is some 80,000,000 tons. Its high percentage of phosphorus classes it as a second class ore, and consequently the price is low. It is becoming a common practice to mix it with pure Brazilian ores, so that the pernicious effect of 0.17 per cent. phosphorus is not so much felt.

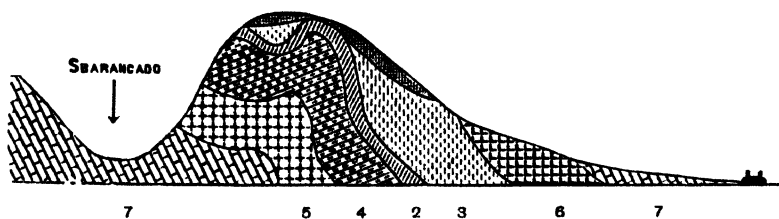
Although the writer has the honour of being manager of the Usina Wigg establishment, he hopes that he has succeeded in making this paper quite unbiassed and as complete as possible, and thus an authoritative statement with regard to this important industry.

He has to thank Mr. Wigg for his help and consent to the publishing of the paper, and Mr. O. A. Derby for many valuable suggestions regarding the geological portions, and particularly the hypothesis of the genesis of the ore, which is mainly his.

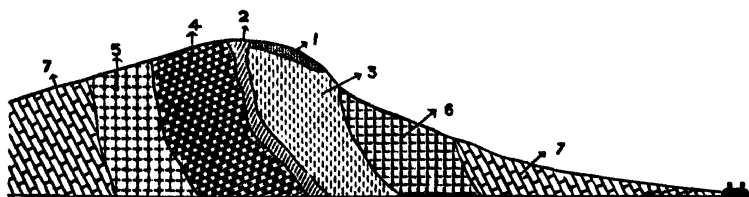
INDEX OF SECTIONS.

- | | | |
|---|---|-----------------------------------|
| 1 |  | = IRON ORE CONGLOMERATE OR CANGA. |
| 2 |  | = MANGANESE ORE BED. |
| 3 |  | = ITABIRITE OR JACUTINGA. |
| 4 |  | = EARTHY IRON AND MANGANESE ORES. |
| 5 |  | = WHITE LIMESTONE. |
| 6 |  | = GREY LIMESTONE. |
| 7 |  | = MICACEOUS SCHISTS. |
| 8 |  | = CENTRAL RAILWAY OF BRAZIL. |

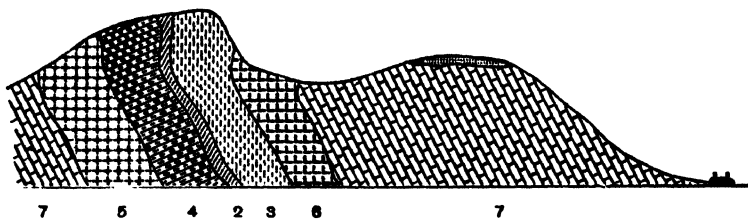
SECTION A.—KIL. 500.



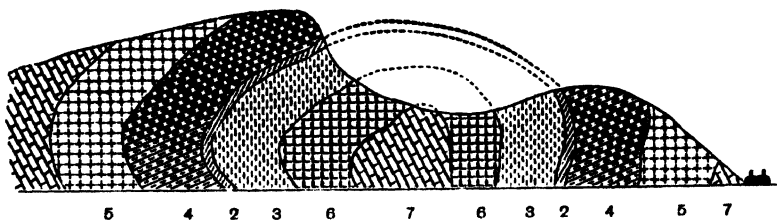
SECTION B.—KIL. 501.



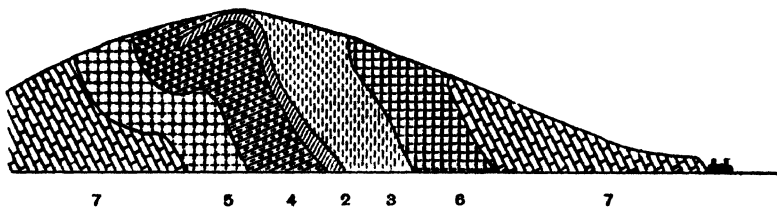
SECTION C.—KIL. 502.



SECTION D.—KIL. 503.



SECTION E.—KIL. 504.



SECTION F.—BOCAINA.

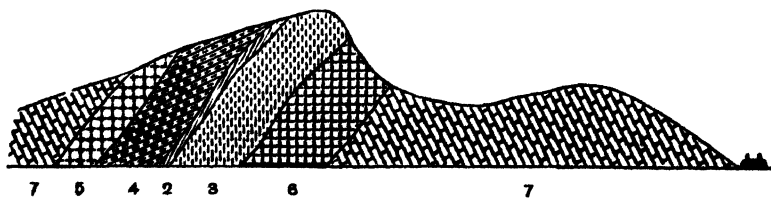


PLATE V.



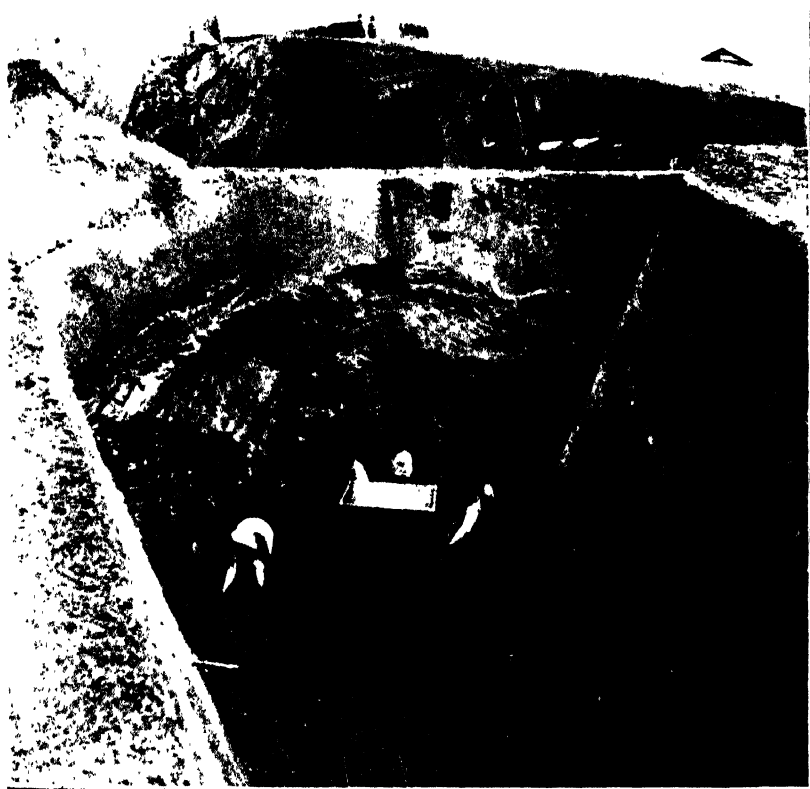
Folding of Jacutinga

PLATE VI.



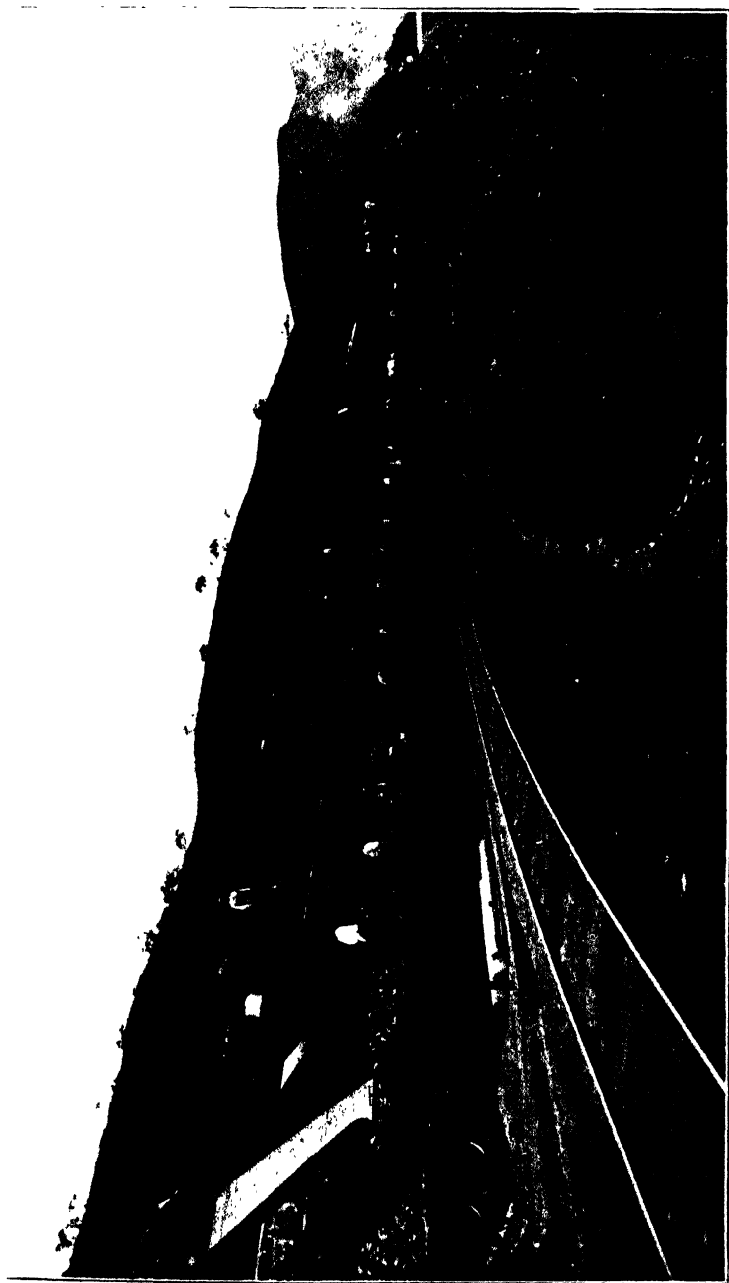
Loading Bins, Kil. 501

PLATE VI.



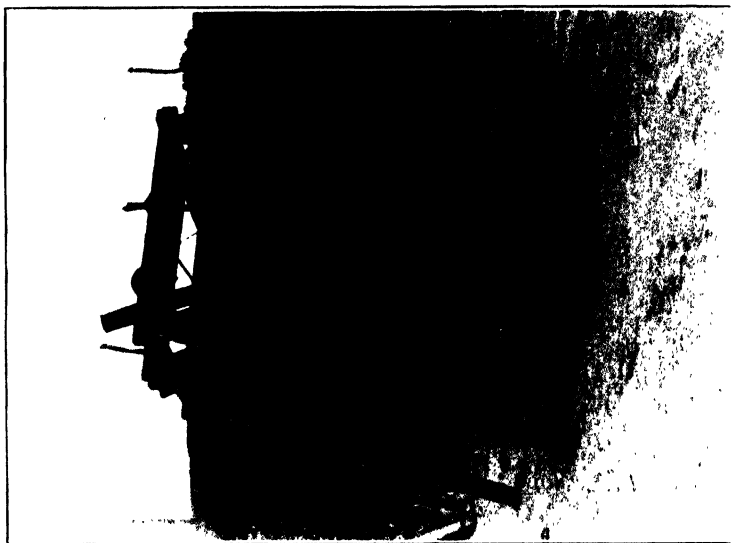
Open Quarrying, showing Bed in situ, Kil. 501

NAWAF SALLABUNG BARADUN



Railway Siding, Kil. 501

PLATE VIII.



Head Gear of a Level Shaft

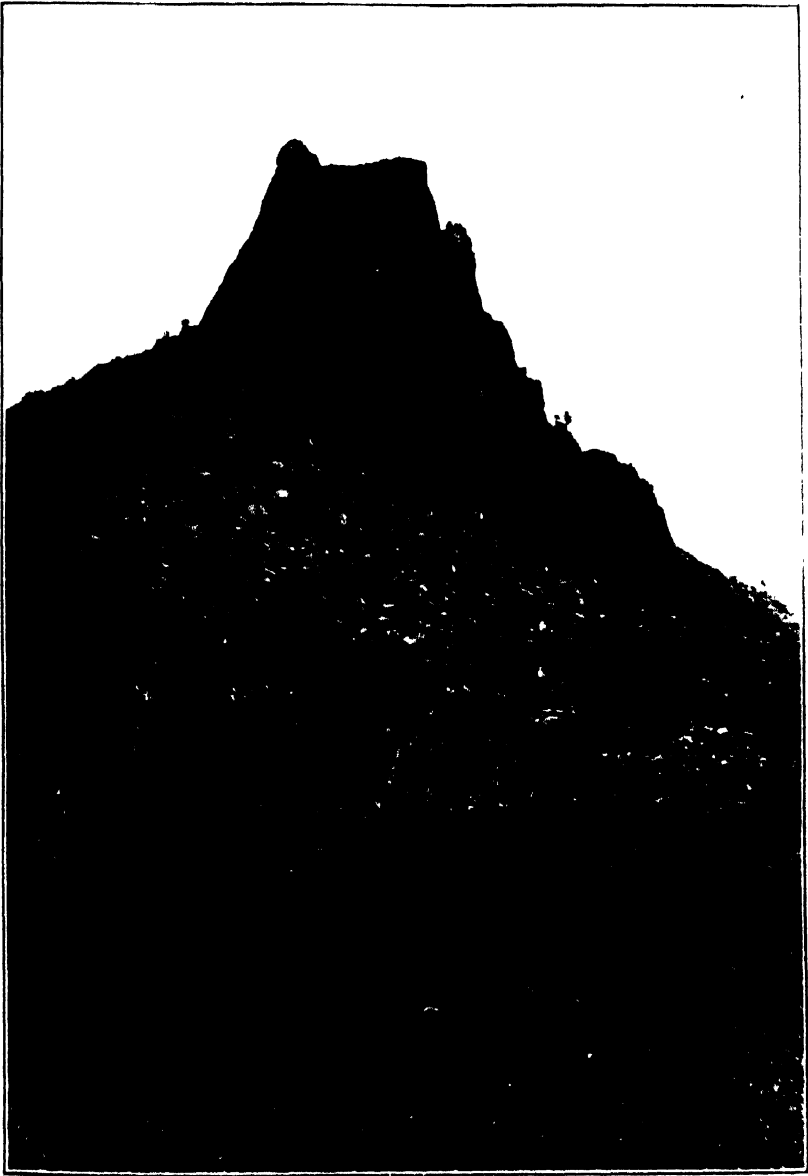
PLATE VIII.



Inclined Plane, Kil. 501



General View of Mines



Peak of Itabira

DISCUSSION.

Mr. ERNEST K. SCOTT said that he was very sorry that the conditions were such that his brother could not be present to introduce the paper and answer any questions personally. He would draw their attention to the analyses of one of the first cargoes of manganese ore shipped from the Usina Wigg mines in 1895, and of a cargo in 1899. From these it would be seen that the manganese percentage was over 55, this percentage being kept up by careful mining and the taking of regular analyses as the work at the mine proceeds. Nearly all the ore shipped from the district in question had been sent to Messrs. Carnegie & Co. and to Messrs. Bolckow, Vaughan, & Co. Now several other companies besides the Usina Wigg had come in, and, as would be seen from the statistics given, the output was rapidly increasing.

A statement had got into the papers some little time ago—it was an old statement published as new, and was somewhat to the effect that a gentleman had been up to the Burnier manganese mines, and that he thought the methods were old-fashioned. Of course when the manganese mines were first opened the ore was quarried or worked open-cast. Now, however, on the Usina Wigg properties at any rate, an elaborate system of underground mining had been evolved, and the ore was being taken out with great regularity and with a minimum risk to the workmen. He (the speaker) thought that his brother's paper was a complete answer to the question as to whether these mines were conducted in an up-to-date manner or not.

Mr. H. BAUERMAN said that he did not know this particular locality. The paper was a very interesting one, and he had no doubt that the mines were exceedingly well described. Reference was made in the paper to Mr. Derby, and he could perfectly well corroborate what was said. He had been to the district in question with Professor Derby many years ago, and there was a very curious mass of iron ore in a decomposed volcanic rock, and they hunted about for several days to see where they could find a piece of the ore in the rock. The whole
1900.—i. o

country was decomposed down in such an extraordinary manner that it was very difficult to say whether one stood on loose stuff or not.

The Right Hon. Sir BERNHARD SAMUELSON, Past-President, said that the sketch accompanying the paper showed where the deposits lay that had been described at length by Mr. Scott. They were at a considerable distance from the shipping port. But the sketch also showed a deposit at Nazareth immediately adjoining the Port of Bahia, which would appear to be very favourably situated for shipment. Could Mr. Scott give any information about this deposit which was not described in the paper? There had been a good deal of manipulation as regards the railway rates by the Brazilian Government, and the deposit at Nazareth would apparently be free from this drawback.

CORRESPONDENCE.

Mr. ORVILLE A. DERBY (São Paulo, Brazil) sent the following communication:—

Mr. Scott's study on the manganese ores of the vicinity of Ouro Preto, quite aside from its purely industrial importance, seems to me to be a valuable contribution to our knowledge of an extremely interesting and little known region, and to that of the question of the genesis of a large class of iron and manganese ores.

Being somewhat familiar with the region, and having for some years past paid some attention to the question of the genesis of iron ores, I had long been interested in the apparent association with limestone of the quartzose iron ores (itabirites) of the district in question, and on becoming acquainted with Dr. J. H. A. Vogt's work, *Salten og Ranen*, in which the similar iron (and manganese) ores of Norway were referred to original carbonates, I suggested to my geological friends of the Ouro Preto Mining School that this was a very plausible working hypothesis to be applied to the ores then being developed in their region. About a year ago I had occasion to make a flying visit to Ouro Preto,

and, under the guidance of Mr. Scott, to go over the principal mines described in his paper, and I was greatly interested to find that the sections that he had worked out independently and without preconceived geological notions showed the most intimate relations between the iron, manganese, and limestone beds.

As regards these sections, it may be remarked that, having been twice over the ground, I found them substantially correct, although it is somewhat doubtful if the apparent duplication of the ore bed at the point shown in Section D is not an effect of faulting rather than of folding, as Mr. Scott has interpreted it. This, however, is a minor question, and has no bearing on the essential fact well brought out by these sections. This is, that for a distance of five or six kilometres there is a continuous bed of manganese ore with a quartzose iron ore and a limestone on one side, and earthy beds and another limestone on the other, and that the wing of the broken fold in which these beds occur varies in position, so that the foot wall of one place becomes the hanging wall of another, making the true order of succession uncertain. There are, furthermore, strong indications that this series has a much greater extension, and that these same conditions are substantially repeated in the various outcrops that occur at intervals from Miguel Burnier to Ouro Preto, a distance of forty-three kilometres by a very crooked railroad. The Bocaina working is possibly a western extension of this same ore line, but in this case there has been a dislocation by a giant fault.

The earthy material between the ore bed and the white limestone in Section B offered a tempting subject for my favourite pastime of "mud geology"—the attempt to trace decomposed material back to the original rock types—and specimens were taken for examination in the laboratory. To my great surprise, I found that these apparently clayey layers contained no clay at all, but were largely soluble in hydrochloric acid, leaving a more or less abundant residue of pure quartz sand with traces of rutile. I found also by a quantitative test that the limestone contained a relatively large proportion of iron and manganese, and that it gave on solution a residue of quartz, pyrite, and rutile, so that, if decomposed, it would leave a residual deposit of earthy hydrated iron and manganese oxides with quartz and rutile, only differing from the earthy layers in the relative proportions of

these ingredients. In view of these observations it was suggested to Mr. Scott that analyses should be made of all the different layers and of the two limestones, with the results given in his paper. From the character of the material and from the results of the microscopic examination of corresponding samples, it is certain that water must have been the principal, if not the only, undetermined element, and that these earthy beds consist essentially of hydrated oxides of iron and manganese (with a small but constant percentage of alumina, probably in the state of hydrargillite or bauxite), with a greater or less admixture of quartz. They are thus true ores, in the scientific if not in the industrial sense, and are evidently allied with the commercial ore on one side, and with the limestone on the other. The most plausible hypothesis of the origin of such material is that of the decomposition and leaching of a more or less siliceous limestone containing a greater or less proportion of iron and manganese carbonates, and the conditions of geological occurrence are extremely favourable for this hypothesis. Moreover, it was found that the more siliceous layers, such as Nos. II.-IV., gave no residue of unmistakable clastic origin (rolled grains of quartz, zircon, &c.), such as would almost infallibly be present if they were original sandstone deposits, as would naturally be suggested by their present composition.

Mr. Scott's sections and analyses afford, therefore, a very pretty and almost absolutely conclusive demonstration that the whole series from the ore layer to the white limestone was originally a succession of limestone layers with varying proportions of metallic carbonates and of siliceous impurities, and thus also of varying degrees of resistance to decay. The purest calcareous layer has resisted to the present time, those between it and the ore probably decayed in a comparatively recent period, and the ore body itself probably at a still earlier period, having since passed through conditions favouring a more or less complete dehydration and recrystallisation of the metallic oxides, which in its case were almost exclusively of manganese. In the case of No. I., the layer next to the limestone, we have only to imagine a moderate decrease in quartz and a restoration of the easily leachable materials (lime and magnesia with the necessary amount of carbonic acid) to give the limestone itself, and,

on the other hand, to imagine a decrease in quartz and a corresponding increase in the metallic oxides to give No. VI., the layer next to the ore, which in turn, with an imaginary almost complete substitution of the iron oxide by that of manganese, gives the ore body itself. All the variations in composition, resistance to decay, &c., here imagined are not only quite conceivable, but are of current occurrence in all extensive calcareous deposits.

Moreover, in the case of material like that of layers Nos. III. and IV., we have only to conceive of a process of dehydration, producing the transformation of limonite into hæmatite, to obtain a fair representation of the itabirite layers on the other side of the ore bed and connecting the series above described with the grey limestone. This gives a very plausible hypothesis for the origin of these layers, also for an original ferruginous limestone. This hypothesis, however, involves that of an ancient decomposition and leaching prior to the metamorphism of the entire series, and elsewhere (in recent contributions to the *American Journal of Science*) I have attempted to show from some of the argillaceous rocks of the same region and geological series that such a process probably took place.

In a recent visit to the Pequiry mine, which, according to the information received from Mr. Scott and others familiar with the district, may be taken as typical of the Lafayette group of mines, I had occasion to verify Mr. Scott's assertion that the geological conditions are entirely different from those of the district about Miguel Burnier and Ouro Preto. The predominant rocks are gneiss and mica schist, with frequent injections of granite, and, with the exception of occasional spurs and outliers from the Ouro Preto district that have nothing to do with the manganese mines, there is a complete absence of the calcareous and ferruginous beds that are so characteristic of that district. The ore body, which is now well opened and is being actively worked, has the appearance of an *Eiserner Hut*—the decomposed portion of a vein or dyke—and both foot and hanging wall are of decomposed granite. What the original material can have been it is difficult to imagine, but it is absolutely certain that it could not have been a sedimentary limestone, like that of the deposits

above discussed. The ore is comparatively pure and affords no residue that will give a clue to its origin. The only extraneous matter observed in the ore body was a small dyke-like stringer of kaolin, evidently derived from some decomposed silicate, near the hanging-wall, and a larger and also dyke-like layer near the foot-wall, that on the ground was taken to be quartzite, but on examination proved to be composed almost exclusively of finely granular manganese garnet.

Turning now to the more purely industrial side of Mr. Scott's paper, it is evident that ore bodies of the character there described, instead of being mere pockets as is common with manganese ores, are likely to have great extension both longitudinally and vertically, and that, from a miner's point of view, the limitations for working will be established solely by the lateral extension and the quality of the ore, and by other considerations quite independent of the ore body itself. As already stated, the ore body that commences at Miguel Burnier has a proven length of 5 or 6 kilometres, and a probable one many times greater. It has been proven in depths to 130 metres from grass, and there are no apparent reasons for supposing that it will not continue without material change of character as far as it is practical to follow it. Moreover, such a bed is liable to be frequently repeated by faulting and folding, and it is probable that some of the points prospected off from the line above indicated are genetically related to it, while there are indications that others are of a different character and origin, and perhaps also different from those of the Lafayette district. It is to be presumed, also, that the limestone and itabirite formation, which is very widespread in this part of Minas Geraes, will prove to be accompanied by manganese ore in other districts, and, in fact, some three or four such districts are already known in which the surface indications are reported to be quite as promising as were those at Miguel Burnier before mining operations were actually commenced.

With the mode of occurrence characteristic of the Lafayette district the probabilities of great longitudinal and vertical extension are less clear. The openings are too small, or have been too superficially examined, to give safe indications, but the surmise may be ventured that the ore bodies will prove to be of

the nature of chutes or segregated masses, with a liability to change in character below drainage level. These ore bodies appear to run somewhat wider than the mean of those of the Miguel Burnier district, and the number already known indicates that more may be expected in the enormous area occupied by the country rocks in which they occur. The working at Pequiry has developed a fine body of ore that is believed to be marketable even with the present high requirements, and the same may happen at other points, although Mr. Scott is undoubtedly right in considering the Lafayette type of ore as more subject to deleterious admixtures than that of Miguel Burnier.

In conclusion, it may be taken as certain that, so far as the natural conditions of quantity, quality, and facilities for mining are concerned, the manganese ore region of Minas Geraes can easily satisfy all demands that are likely to be made upon it for a long time to come.

Mr. JOHN PATTINSON, F.I.C. (Newcastle-upon-Tyne), wrote :—

I have read Mr. Scott's paper on the manganese ores of Brazil with interest. I have had the opportunity of examining several cargoes of Brazilian manganese ores, both from the mines of Mr. Carlos Wigg and from other Brazilian manganese ore mines, and I find that these cargoes may be divided into two qualities—those containing about 0·05 per cent. of phosphorus or less, and those containing *more* than this quantity. Both classes of ore are, as a rule, low in silica, some of the cargoes containing only from 1 to $1\frac{1}{2}$ per cent., and this constituent seldom exceeds 3·5 per cent. The cargoes most free from phosphorus always contain a large proportion of a soft porous ore, which has the property of holding an enormous quantity of water. This constitutes the chief drawback to this otherwise excellent mineral. The moisture in cargoes of this class is seldom below 14 or 15 per cent., and sometimes rises to upwards of 20 per cent.; therefore not only has freight to be paid for carrying water instead of ore, but this water has to be evaporated in the blast-furnace at the expense of fuel, at the same time reducing the temperature of the gas and charging it with moisture. We have, therefore, suggested to some of our clients who are interested in some of the Brazilian mines, that it might prove to be economical to

calcine this ore in Brazil. Calcination would not only expel the hygroscopic moisture, but also the combined water and some of the oxygen of the ore, and would increase the percentage of manganese in the ore by from 20 to 25 per cent. of its original manganese contents.

The cargoes containing more than about 0·05 per cent. of phosphorus consist chiefly of a harder and more crystalline mineral, and are much drier, the moisture being usually from 3 to 7 per cent.

Mr. H. G. TURNER, who had read Mr. Scott's account of the manganese industry of Brazil with very great interest, sent the following communication:—

It is a coincidence that the development of the manganese deposits of Brazil is emulated and equalled year by year by the parallel business in Indian manganese ores. Beginning about the year 1893 with small shipments, the exports of Indian ore in 1899 exceeded 80,000 tons. Most of the Indian ore is phosphatic, containing more than 0·125 per cent. of phosphorus, which is the dividing line between phosphatic and non-phosphatic ores insisted on by the consumers of Indian ore. Recent discoveries have been made of Indian ores which contain less than 0·1 per cent. of phosphorus. These ores are very rich in manganese, and they compare favourably with the analyses of the Brazil ores quoted by Mr. Scott. The analyses of the new Indian ores are as follows:—

	Per Cent.	Per Cent.	Per Cent.
Manganese	54·93	53·42	58·45
Iron	4·82	7·02	3·69
Silica	6·94	5·26	5·40
Phosphorus	0·53	0·59	0·82
Combined water	1·92	...	...

These ores are hard ores. They exist in great rock-like masses, which are blasted into fragments suitable for carting and railing to the coast. The mineral is well suited to blast-furnace work, containing very small percentages of moisture.

It is difficult to hazard an opinion as to the amount of ore in sight or just beneath the surface. It would be an easy matter to cube out vast quantities, but this mode of estimation is fallacious. It is sufficient to say that there is ample mineral to

supply a large proportion of the present requirements of the market.

From an economic and administrative point of view, the manganese industry is of great importance to those parts of India where it is being established, for scarcity, and sometimes famine, is the lot of the inhabitants.

The deposits worked during the last six years gave employment to thousands of labourers who previously existed on agriculture, and the new deposits alluded to above will likewise be of great benefit to the people of the part which is about to be opened out.

It probably costs as much to excavate and clean a ton of manganese ore in India as it costs in Brazil. But inasmuch as the hands employed in the former country are numbered by thousands, the wages being but a few pence a day, the benefits from an industry of the sort are distributed among hundreds of families, and form a very sensible addition to the wages fund of the country. The example afforded by the manganese industry already established is an earnest of what can be done in developing the mineral resources of India.

The minerals in India which come within the purview of the Iron and Steel Institute are iron ore, chrome ore, manganese, coal, magnesite, corundum, graphite, mica, and plumbago. There is still considerable delay and difficulty in obtaining concessions from some of the Governments in India for working these minerals. This arises not so much from a lack of desire to develop these industries as from a want of experienced advisers, and from the traditional system of references from one authority to another.

Mr. E. K. SCOTT, in replying, said that there was just one point he would like to refer to, and that was with reference to the railway up to Miguel Burnier. Before the manganese mines were at work the trains used to go up with food stuffs and machinery, and come down only lightly loaded; but now they took up the supplies to the interior and came down with the manganese. It was thus possible for the railway to carry the ore at a cheaper rate than would otherwise be the case. What was badly

wanted was that the wide gauge should be adopted throughout. At present it changed to metre gauge at Lafayette.

The PRESIDENT, in proposing a vote of thanks to Mr. Scott for his paper, said that he need not remind them that Mr. Scott had already given them a very important paper on Elba, and he had now earned their gratitude by his last paper.

The following paper was then taken as read :—

THE THEORY OF SOLUTION OF IRON
AND STEEL.

BY BARON JÜPTNER VON JONSTORFF.

IN the former studies made by the author,* only those points in the physical chemistry of the subject were considered which had reference to the correlation between the osmotic pressure and the temperature of separation of the (fluid or solid) solutions, and by such means we have in many cases succeeded in setting up hypotheses which require further strengthening or investigating.†

In the following studies we hope to investigate whether the laws of chemical mechanics can be employed in the case of the iron-carbon alloys. As in our former studies, this will be done, not with the object of obtaining absolute values (which is still impossible even to-day, owing to the lack of many important data), but rather of pointing out what conclusions the present available experiments promise to give, and to invite the search for those fundamental data which are yet wanting for a vigorous employment of theory.

In the solid iron alloys, perhaps also now and again in the fluid ones, we have to deal throughout with heterogeneous systems, that is to say, with systems which, by their non-similar chemical or physical constitution through a determinate range of temperature, are separated from one another.

If one finds a system under given conditions remaining in a certain state, we say it is in *equilibrium*. We must, however, distinguish between *stable* and *unstable* equilibrium.

The first occurs when *at least* n different sorts of molecules combine in order to form a system consisting of $n + 1$ different phases. The stable heterogeneous equilibrium is thus charac-

* *Journal of the Iron and Steel Institute*, 1897-99.

† Thus, at the Spring Meeting last year, the austenite curve, AU, referred to 0 per cent. austenite, that is to say, to the composition of martensite under the conditions stated, and not to austenite.

terised by the fact that only a single equilibrium pressure belongs to any determinate temperature.

With condensed systems (Van't Hoff), that is to say, such in which no gas-forming phase is present (and with such we are in this case exclusively dealing), the only difference appears to be that the alteration of volume brought about by the change is relatively very small, and therefore the influence of the pressure on the change of temperature is very insignificant. From this it follows that at higher temperatures stable systems form with absorption of heat, and *vice versa*.

A stable heterogeneous equilibrium of this kind is present in iron-carbon alloys:—

1. On the melting and freezing of fluid eutectic alloys. Freezing is effected, as a matter of fact, with development of heat, and liquefaction with absorption of heat.

2. By the change of martensite into pearlite, which also takes place with the evolution of heat (critical point Ar_2).

3. By the separation of ferrite from martensite at Ar_2 in steels low in carbon.

All these changes take place with evolution of heat, made visible during continuous cooling down. If we examine the change of martensite into pearlite, it can be shown, corresponding to the above, that the specific gravity of martensite is smaller than pearlite; thus Hausmann found for the specific gravity of Solingen cast steel:—

	Unhardened = sw.	Hardened = sh.	sw. sh.
Non-welding cast steel	7.8439	7.7672	1.0098
Weldable	7.8577	7.8010	1.0072

That is to say, that the volume of hardened steel, that is, steel in which martensite predominates, and consequently martensite itself, is at ordinary temperatures some 8 per cent. greater than that of annealed steel (pearlite).

For unstable equilibrium the equilibrium coefficient is constant for one and the same temperature, that is to say, is independent of the mass relation of the reacting materials. Its

alteration with the temperature is expressed by Van't Hoff's equation :—

$$\frac{d \ln K}{dt} = \frac{q}{RT^2}$$

in which K is the equilibrium coefficient, q the rise of heat of the reaction measured in absolute temperature, T , and R the gas constant.

On heating up a chemical system, it will be found that a shifting of the equilibrium takes place in the direction towards which the reaction tends under absorption of heat.

If we apply this law to the separation of ferrite from martensite, that is, to the critical temperature curve Ar_1 and Ar_{1-2} (but not to Ar_2 , at which stable equilibrium prevails), and to the separation of cementite and martensite and to the 0 per cent. austenite curve, it follows that the separation of ferrite or cementite from martensite, as well as the formation of martensite from austenite, takes place with evolution of heat, but the reverse reactions with absorption of heat.

In order now to prove in what way further conclusions may be arrived at, we will take into consideration the rise of temperature which, according to Osmond and Werth,* is obtained on the solution of quenched and annealed iron samples in $CuCl_2$.

The chemical analyses of the samples employed gave :—

	Ingot Iron.	Soft Steel.	Tool Steel.	White Swedish Pig Iron.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon	0.168	0.542	1.170	4.100
Silicon	0.038	0.105	0.044	0.225
Phosphorus	0.024	0.058	0.033	0.018
Sulphur	0.038	0.027	0.018	0.040
Manganese	0.170	0.510	0.180	0.120
Iron	99.562	98.758	98.159	95.497
Total	100.000	100.000	100.000	100.000

For the first approximation we will neglect the content of other constituents present and look upon the above samples as pure iron-carbon alloys. We must also for the time ignore the formation of polymerised iron carbides.

* *Annales des Mines*, vol. viii. 1885, p. 1.

For the calculation of the micrographic composition we will follow the information published by Sauveur,* from which we obtain :—

(a) For metal with less than 0·8 per cent. carbon :

a. Annealed—

$$\text{Carbide (Fe}_3\text{C)} = \frac{100 \times \text{C}}{6\cdot67} = 15 \times \text{C.}$$

$$\text{Pearlite} = \frac{100}{12} \times \text{Carbide.}$$

$$\text{Ferrite} = 110 - \text{Pearlite.}$$

β. Quenched—

$$\text{Martensite} = 100.$$

(This equation only holds good when the carbon reaches at least 0·14 per cent.)

(b) For metal with more than 0·8 per cent. carbon :

a. Annealed—

$$\text{Carbide (Fe}_3\text{C)} = 15 \times \text{C.}$$

$$\text{Free iron} = 100 - 15 \times \text{C.}$$

$$\text{Pearlite} = \frac{100}{88} \times \text{free iron.}$$

$$\text{Cementite} = 100 - \text{Pearlite.}$$

β. Quenched—

$$\text{Cementite} = \frac{100 \times \text{C} - 90}{5\cdot77}$$

$$\text{Martensite} = 100 - \text{Cementite.}$$

From the above the micrographic composition† of the samples may be calculated, as follows :—

		1.	2.	3.	4.
Annealed	{ Ferrite . . .	79·0	32·83		
	{ Cementite . . .			6·33	56·2
	{ Pearlite . . .	21·0	67·17	93·66	43·8
Hardened	{ Cementite . . .			4·7	55·0
	{ Martensite . . .	100·0	100·0	95·3	45·0

The above figures, rigidly taken, represent volume percentages, but on account of the slight differences in the specific gravities may be taken as percentages by weight.‡

* *Transactions of the American Institute of Mining Engineers, Colorado Meeting, September 1896*; and *Journal of the Iron and Steel Institute, 1896, No. II. p. 191.*

† It is much to be regretted that no direct measurement of the microscopic composition exists, since thereby no inconsiderable source of errors would be avoided.

‡ The specific gravities of the various constituent forms of iron are unfortunately for the greater part still unknown, whereby a further source of error arises.

The chemical heat of solution on dissolving 1 grm. of the metal in CuCl_2 is:—

Calories per 1 grm. of Metal.	1.	2.	3.	4.
Quenched *		693·4893	641·4670	508·4339
Annealed	671·7014	659·2104	591·7592	442·1164
Difference		36·2789	49·7078	66·3175

The above may be expressed as quenched by the following equations:—

Test No.	Progress of Hardening.		
1.	100 martensite = 79·0 ferrite	+ 21·0 pearlite.	
2.	100 " = 32·8 " "	+ 67·2 " "	
3.	95·3 " = 1·6 cementite + 93·7 " "		
4.	45·0 " = 1·2 " "	+ 43·8 " "	

We find, therefore, as otherwise known, that by the transformation of martensite into pearlite, according to the carbon percentage, either the separation of free ferrite or of cementite takes place. This condition must, on account of the want of data, remain uncalculated. Fortunately the quantity of free ferrite or cementite separated at A_{r_3} is rather small. According to the above data, the quantity of free cementite (expressed per 100 parts of martensite) appears to rise with the carbon percentage, for we find with—

1·7 per cent. carbon	1·678 per cent. of martensite.
4·2 " " "	2·667 " " "

Let us now consider the rise of temperature on the solution of the above samples, and compare them with the results one would obtain if they consisted merely of a mixture of their elementary constituent parts. The calculation on this latter standpoint is based on the following data:—

* Unfortunately the quenching temperature is unknown.

Heat of Solution on Dissolving one Gramme.	Calories.
Iron ($\text{CuCl}_2 + \text{Fe} = \text{FeCl}_2 + \text{Cu}$)	667.8
Manganese ($\text{CuCl}_2 + \text{Mn} = \text{MnCl}_2 + \text{Cu}$)	1189.1
Silicon ($4\text{CuCl}_2 + 2\text{H}_2\text{O} + \text{Si} = 4\text{CuCl} + 4\text{HCl} + \text{SiO}_2$)	3150.0

We will neglect the remaining elements.

From the above we obtain :—

a. SAMPLE 1.

Heat of solution on dissolving 1 grm. in CuCl_2 , calculated—

Gramme.	Calories.
0.99562 Fe	664.8706
0.0017 Mn	2.0215
0.00038 Si	1.1970
Total	668.0891
Heat of solution of the annealed sample obtained } direct	671.7014
Difference	3.6123

Thus we find, as a matter of fact, that the metal evolves on solution more heat than is calculated from its theoretical composition. This excess of heat must result from the composition of the iron carbide contained in the pearlite, and from this it may be calculated that the heat of formation of 1 grm. of iron carbide in pearlite is $-\frac{3.6123}{0.0252} = -143.3$ calories.

β. SAMPLE 2.

Heat of solution of 1 grm. in CuCl_2 , calculated—

Gramme.	Calories.
0.98758 Fe	659.5059
0.0051 Mn	6.0644
0.00105 Si	3.3075
Total	668.8778
Rise of temperature of the annealed metal by } direct estimation	659.2104
Difference	9.6674

The annealed metal gives on solution in CuCl_2 , 9.6674 calories less heat than is required by theory, from which we find that the heat of formation of 1 grm. of iron carbide of the pearlite

Since in both cases only ferrite and pearlite can be present, the striking want of agreement between both values points either

(which seems the more probable) to the formation of polymerised carbides, or to an experimental error in the calorimetric determination. We will ignore the further calculation of both values.

γ. SAMPLE 3.

1. From $\left[\frac{\text{Fe}_3 + \text{C}}{180} \right] = -143.3$ calories—

Heat given out on solution of 1 grm. in CuCl_2 , calculated—

Gramme.	Calories.
0.98159 Fe	655.5058
0.0018 Mn	2.1404
0.0044 Si	13.8600
Total	671.5062
Heat given out by the annealed sample by direct experiment	591.7592
Difference	79.7470

The annealed sample contained in this case 0.1142 grm. iron carbide as pearlite, and 0.0633 grm. iron carbide as *free cementite*. If we put the heat of formation of 1 grm. of free carbide at -143.3 calories as above, we obtain for the heat of formation of 1 grm. of free carbide $\frac{0.1142 \times 143.3 + 79.7470}{0.0633} = +1518.4$ calories.

2. From $\left[\frac{\text{Fe}_3 + \text{C}}{180} \right] = +119$ calories—

In a perfectly similar manner the heat of formation of 1 grm. of free carbide is $\frac{79.7470 - 0.1142 \times 119}{0.0633} = +1045.1$ calories.

δ. SAMPLE 4.

1. From $\left[\frac{\text{Fe}_3 + \text{C}}{180} \right] = -143.3$ calories—

Heat given out on solution of 1 grm. in CuCl_2 , calculated—

Gramme.	Calories.
0.95497 Fe	637.7290
0.0012 Mn	1.4269
0.00225 Si	7.0875
Total	646.2434
Direct estimation of heat given out in the annealed state	442.1164
Difference	104.1270

From this it follows, if we take the heat of formation of pearlite carbide, as above, to be constant, the heat of formation of 1 grm. of free carbide is $\frac{0.052 \times 143.3 - 104.1270}{0.0590} = +198.8$ calories.

2. From $\left[\frac{\text{Fe}_3 + \text{C}}{180} \right] = +119$ calories.

Heat of formation of 1 grm. of free carbide = +173 calories.
1900.—i.

Thus we see that the value obtained for the heat of formation both of the pearlite carbide and of that of the free cementite fluctuates very considerably, which may be looked upon as confirming the theory according to which many polymerised carbides exist in iron. The strikingly small value for the formation of free carbide in Sample 4, namely, 198·8 or 173 calories, can be explained, taking into consideration the austenite curve of the often-referred to hypothesis that austenite contains a considerable quantity of free carbon, on the supposition that, with 4·1 per cent. carbon, a considerable part of the carbide is dissociated immediately above A_{r_3} , combines again at A_{r_3} to form carbide, and is thereby not so completely polymerised as the remainder of the carbide.

We will now turn our attention to the energy-difference between the quenched and the annealed samples, which correspond indeed to the difference in the rise of heat on solution.

The alteration of condition taking place on quenching consists in the Samples 3 and 4, which we will now consider, in the separation of carbide from martensite above A_{r_3} , in the conversion of martensite into pearlite at A_{r_3} , and in the allotropic change of β or γ iron into α -iron, likewise at A_{r_3} . We will denote this heat given out on the doubtful conversion of 1 grm. of martensite into pearlite by Q_m , that given out on the conversion of 1 grm. β or γ iron into α -iron by Q_{al} , and finally the heat gained in the separation of 1 grm. carbide from martensite by Q_{fc} . Then we have for Sample 3 :—

$$95\cdot3 Q_m + 98\cdot159 Q_{al} + x Q_{fc} = + 4970\cdot78 \text{ calories.}$$

For Sample 4—

$$45\cdot0 Q_m + 95\cdot497 Q_{al} + y Q_{fc} = + 6631\cdot75 \text{ calories.}$$

x and y are not known, since the pieces in question were not microscopically studied. Still we may, as a near approximation, insert the calculated value of free cementite (4·7, corresponding to 55·0), and obtain then for Sample 3 :—

$$95\cdot3 Q_m + 98\cdot159 Q_{al} + 4\cdot7 Q_{fc} = + 4970\cdot78 \text{ calories.}$$

For Sample 4—

$$45\cdot0 Q_m + 95\cdot497 Q_{al} + 55\cdot0 Q_{fc} = + 6631\cdot75 \text{ calories.}$$

Unfortunately in these two equations we have three unknown quantities, so that the determination of these latter is not possible. In order, however, to get at a first approximation, we will adopt Roberts-Austen's figures for the alterations in the specific heat of the allotropic forms of iron at Ar_3 , 2·86, at Ar_2 about 1, that is, in round figures, 4 calories; so we obtain

$$95\cdot3 Q_m + 392\cdot1 + 4\cdot7 Q_{fe} = + 4970\cdot78.$$

$$45\cdot0 Q_m + 382\cdot0 + 55\cdot0 Q_{fe} = + 6631\cdot75.$$

or

$$95\cdot3 Q_m + 4\cdot7 Q_{fe} = 4578\cdot7.$$

$$45\cdot0 Q_m + 55\cdot0 Q_{fe} = 6249\cdot8.$$

And from this it results that the heat of solution of 1 grm. of carbide in martensite:— $Q_{fe} = - 76\cdot9$ calories; the heat of conversion of 1 grm. of martensite into pearlite = $Q_m = 45$ calories.

In Sample 2 the alteration of condition brought about by quenching consists in the allotropic conversion of iron, in the separation of ferrite from martensite, and in the conversion of martensite into pearlite. If we choose for the amount of heat hereby set free (for 1 grm. of the material in question) the expressions Q_{al} , Q_{fer} , and Q_m , we have, by substituting the above established values $Q_{al} = 4$ and $Q_m = 45$:—

$$98\cdot157 Q_{al} + 67\cdot75 Q_m + 32\cdot25 Q_{fer} = 3627\cdot89.$$

or

$$392\cdot6 + 3048\cdot8 + 32\cdot25 Q_{fer} = 3627\cdot89.$$

and

$$Q_{fer} = 5\cdot78 \text{ calories.}$$

If we adopt the earlier assumption, that Sample 4 above Ar_3 contains considerable quantities of dissociated iron carbide and also of free carbon, we should of course obtain other values. We can, however, readily perceive from the above considerations what an important bearing thermo-chemistry possesses for a knowledge of the constitution of the alloys of iron and their alterations of state.

VOTES OF THANKS.

Sir JOHN ALLEYNE, Bart. (Vice-President), then moved the following resolution:—"That the best thanks of the Iron and Steel Institute are hereby tendered to the President, Council, and Secretary of the Institution of Civil Engineers for the use of the room and the facilities otherwise afforded for the present meeting." He would further add to that, that they were thankful to them, as the leading Institution, for taking such as them under their protective wing, and they were thankful for the great benefit which was afforded to these manufacturing industries by the protection they gave by associating themselves with the Iron and Steel Institute and similar institutions.

Professor HENRY LOUIS seconded the resolution.

The PRESIDENT, in supporting the motion, said that he need not say how very glad and grateful he was, as President, to the Institution of Civil Engineers for their renewed and prolonged hospitalities to them as a body, and he would take care that the vote of thanks was conveyed to them in proper terms when it was carried, as it would be, unanimously.

The resolution was put to the meeting and carried unanimously.

Mr. ANDREW CARNEGIE (Vice-President) said he was charged with the pleasant duty of proposing that the best thanks of the members be given to the President for the highly satisfactory manner in which he had discharged the duties of the chair.

Mr. ARTHUR D. ELLIS seconded the motion, which was carried with acclamation.

The PRESIDENT, in reply to the vote of thanks, said that it was with some regret that he rose to speak, because it was the last time he would preside in that room, although he hoped they would have a pleasant meeting in Paris in September. Some

time ago Mr. Carnegie had proposed to offer a certain sum for a scholarship and a medal that should be offered to the Institute, but of course the details would have to be arranged by the Council.

Mr. CARNEGIE said that the part he had to play was not to allow it to remain in the air. The President was entitled to all the credit of the affair, he having suggested it. It was always the man who worked and put a thing into shape who was entitled to credit, for he had given attention to it. It was not the man who merely gave the money—that was an easy matter.

THE ANNUAL DINNER.

The members of the Institute dined together in the Grand Hall of the Hotel Cecil on Wednesday, May 9th, when the chair was occupied by the President, Sir William Roberts-Austen, K.C.B., D.C.L., F.R.S., who was supported by a number of distinguished guests, and by many of his colleagues on the Council. There were nearly three hundred noblemen and gentlemen present, amongst whom were the following :—The Right Honourable G. J. Goschen, M.P. (First Lord of the Admiralty), the Right Honourable Lord Kelvin, G.C.V.O., the Right Honourable Lord Strathcona, G.C.M.G., Admiral the Right Honourable Sir John C. Dalrymple-Hay, K.C.B., D.C.L., F.R.S., the Right Honourable Sir Bernhard Samuelson, Bart., F.R.S., Past-President, the Right Honourable the Lord Provost of Glasgow, the Master-Cutler of Sheffield (Mr. R. A. Hadfield), the Honourable Sir Charles Free-mantle, K.C.B., the Honourable Lyulph Stanley, Mr. Henri de Wendel, Mr. F. de Wendel, Mr. H. de Wendel, Sir F. J. Bramwell, Bart., D.C.L., F.R.S., Sir Lowthian Bell, Bart., F.R.S., Past-President, Sir James Kitson, Bart., M.P., Past-President, Sir Benjamin Hingley, Bart., Sir Courtenay Boyle, K.C.B. (Permanent Secretary to the Board of Trade), Sir John Evans, K.C.B., the Deputy-Master of the Royal Mint (Horace Seymour, C.B.), Sir Norman Lockyer, K.C.B., F.R.S., Sir Benjamin Baker, K.C.M.G., F.R.S., Sir William Abney, K.C.B., F.R.S., Sir Douglas Fox, Sir John J. Jenkins, M.P., Sir Thomas Wrightson, Bart., M.P., Sir Joseph Leigh, Sir H. B. Robertson, Dr. Ludwig Mond, F.R.S., Major-General F. T. Lloyd, C.B. (Governor of the Royal Military Academy), Professor Sylvanus Thompson, D.Sc., F.R.S., Colonel Bainbridge, C.B. (Director-General of Ordnance Factories), Professor Bauerman, Dr. J. H. T. Tudsbery, Mr. John Colville, M.P., Mr. Delamare-Deboutville, Mr. E. Windsor Richards, Past-President, Mr. Edward P. Martin, Past-President, Mr. William Whitwell, Honorary Treasurer, Mr. G. J. Snelus, F.R.S., Vice-President, Mr. James Riley, Vice-President, Mr. W. H. Bleckley, Vice-President, Mr. Arthur Keen, Vice-President, Mr. S. R. Platt, Vice-President, Mr. David Evans, Member of Council, Mr. Arthur Cooper, Member of

Council, Mr. William Evans, Member of Council, Mr. Tannett Walker, Member of Council, Mr. J. E. Stead, Member of Council, Mr. Adolphe Greiner, Member of Council.

The PRESIDENT, in proposing the toast of "Her Majesty the Queen," said: Many things have happened since we met in this room last year, but the whole course of events has tended to make our revered sovereign more dear to us, if it were possible, than ever before. I reminded the members last year that strength, endurance, tenacity, all attributes of steel, are precisely the qualities we should choose if we wished to express our loyalty and devotion to the throne. Fortunately there is another metallurgical term, well known to all of us, which is the very best we could possibly choose to express the nature of the union by which all parts of the Empire have been joined together, and that word is "welded;" and welded all parts of the Empire have been, not merely by a great heat-wave of enthusiasm, but by the wonderful attractive force which Her Majesty knows so well how to exercise. Since we met here we have as a nation lost many precious lives, but Her Majesty has taught us to press closer together to fill up the gaps which have been caused by the great contest in South Africa, that has already left a record of devotion and courage which has never been surpassed in the history of the British nation. It is with great pride that many members of this great Institute can feel that, by supplying steel and iron of an admirable quality for the use of Her Majesty's forces, that they have taken a great and personal part in the struggle for liberty and civilisation which is now being waged in South Africa. The Queen was pleased to recognise the national importance of the work of members of the Institute when she personally accepted the Bessemer Gold Medal of the Institute, which is the sign of our great industry, and the gracious words with which Her Majesty expressed her direct interest in our Institute will ever be engraven on the hearts of those who accompanied me to Windsor in July last.

The toast was enthusiastically received, and was accompanied with musical honours.

The PRESIDENT, again rising to propose "The Prince and Princess of Wales and the other Members of the Royal Family," said: There is one other toast, closely connected with the last, which is, "The health of the Prince and Princess of Wales and the other members of the Royal Family." His Royal Highness is one of our oldest Honorary

members ; and I may say that, after leaving our meeting to-day in the Institution of Civil Engineers, I hurried to the Imperial Institute, the home of the new London University, in order to be present at the opening of that great university by the Prince of Wales. It is fitting that the greatest city of the greatest empire the world has ever seen should have a university of its own, and the growth in the belief of the great importance of education could not be better shown than by the growth of universities in all our great centres. Nor could the Prince of Wales have shown his interest in scientific and technical work in a better way than by opening the great University of London as he did to-day.

The toast was received with acclamation.

Sir BENJAMIN BAKER, in proposing the toast of "The Navy and the Army," said he had the honour of proposing the toast of "The Navy, the Army, and the Reserve Forces," coupled with the names of the First Lord of the Admiralty and Major-General Lloyd. Four years ago, he, as President of the Institution of Civil Engineers, proposed the same toast, coupled also with the name of the First Lord of the Admiralty, but on that occasion with the name of Sir Redvers Buller for the army. A great deal had happened during the past four years, but he felt sure that not a word said by any one of the three on that occasion would be withdrawn now, but rather be amplified as a consequence of recent experience. The First Lord warned them that there was no finality of design as regards guns, ammunition, or any of the munitions of war. He assured them that neither he nor his colleagues were bound up in coils of red tape, but that it was their bounden duty to investigate every suggestion, whether it came from home or abroad, which was likely to conduce to the improvement of their military and naval resources. The First Lord said, "Obsolete was a terrible word always, and recurring ;" and, as regarded money, he had nothing to reproach himself with, for he had done his best to obtain it, to maintain the efficiency of the naval and military resources of this country. He was quite sure that the First Lord would not wish to retract a single word of that speech. If Sir Redvers Buller were there that night, he would admit frankly that mistakes had been made, because he was the soul of frankness, but that it was not for want of the most splendid courage on the part of officers and men, but from want of experience in certain details of scouting and minor tactics, from the result of which they had lost guns and had had men taken prisoners, causing

rather a shock to the nation. If Sir Redvers were not the modest man that he was, he would, and he could, very reasonably have added : "But what did I tell you four years ago?" He was not here now, but he (Sir Benjamin) would tell them what Sir Redvers told them on that occasion. He said the army was a huge machine ; it was necessary to test such machine in peace if they wanted to make sure that it would perform the duties that they looked for in time of war, and he only wished the country would support the army and give them the opportunity of testing its working in peace. But Sir Redvers added : "Look at the position we are in now. We have a very modest Bill before Parliament for manœuvres to test our army machinery, but the representatives of the public have given notice of 76 amendments to this simple and reasonable suggestion." Now, as a member of the public who was responsible for returning such representatives to Parliament—and they were all members of the public there—they must feel, when they recalled Sir Redvers Buller's words, that if the officers and men sent out to South Africa were in some respects rather apprentices than skilled workmen, that was not Sir Redvers Buller's fault. Sir Redvers clearly warned them four years ago what was necessary, and they, as practical men, knew that if they chose to intrust a rolling-mill or a forge to apprentices, they must blame only themselves if the work did not turn out as well with apprentices, who had not had the opportunity of fully perfecting themselves in the work, as with finished workmen. He could not help thinking that the movers of those amendments to the Manœuvres Bill must reproach themselves now for having caused to be sent out these gallant officers and men to learn their profession amidst a storm of shrapnel and a hailstorm of bullets, when they might, as Sir Redvers Buller pointed out, have learned a great part of their business at home. It would be ungenerous and un-British if they did not consider all these facts when they sat in judgment on officers and men regarding incidents which they had seen reported in the telegrams from the front. He was sure that Sir Redvers Buller, if he had been there, would, as the result of his experience, only impress upon them more strongly than he did four years ago the necessity of the public taking an interest in the training of the army, and insisting on their representatives in Parliament seeing that they had proper opportunities of practice. As regarded himself, he said four years ago that in the no distant future they would have to consider whether the Continental system of compulsory education or our own was the best. In this country compulsory education ended

at childhood ; on the Continent they resumed it again at the dawn of manhood. There a young man was compelled to go to school again, and was not only subject to physical exercises to expand his lungs and develop his muscles, but he received never-to-be-forgotten lessons in obedience, discipline, self-denial, and manliness when serving his time in the army or navy. He trusted the public would impress upon their rulers that it was unfair that their young men had not the same opportunities of resuming their education at that critical period, the dawn of manhood, in the best and cheapest of all schools for such purposes, namely, the navy, the army, and the reserve forces, the subject of his toast that night.

The Right Hon. G. J. GOSCHEN, M.P. (First Lord of the Admiralty), who was enthusiastically received, in replying to the toast said : I rise to return my most sincere thanks for that branch of Her Majesty's forces over which I temporarily have the proud privilege of presiding. I thank you on behalf of the Navy. During the last few days the minds of most men have been turned in the main to the *personnel* of the Navy. London has celebrated the exploits of the Naval Brigade ; London has had the opportunity of seeing samples, if I may use that term in this assembly, of the men whom the Navy turns out. But at no time, whatever attention may be given to the *personnel* of the Navy, can the Lords of the Admiralty forget for one moment the care they have to bestow upon the *matériel* of the Navy. (Cheers.) The finer the crews which are sent out to do battle for the country, the greater the obligation rests upon this country to provide them with the best means of offence and defence. (Hear, hear.) And in that respect I do not forget whom I see assembled in this room to-night. I see the manufacturers of armour-plates. I see here all the men who have turned their best abilities to the manufacture of all those implements of war and implements of defence upon which the security of the country so largely will depend, and my thoughts stray amongst all the terrible complications which surround all the physical and scientific problems with which you, gentlemen, and with which, in a minor part, in a different degree, we at the Admiralty have to contend. My thoughts are fixed on erosion ; on muzzle energy ; on the Krupp process in the hardening of armour-plates ; and on a number of similar complicated problems. We have to find our way through those problems, and we count upon the energy and the industry and the inventive

power of the great men who are gathered together in this Institute, as the manufacturers of steel, as ironmasters, not to forget the scientific men whom you are bound to press into your ranks, the chemists, the metallurgists, and all those men acquainted with those terrible mysteries which we have to try to solve. You have formidable competitors, as you know. Why should it not be so? You know that in every country they are endeavouring to tread upon your heels. You know that you have a formidable competitor in Krupp; you have formidable competitors at Le Creusot, and you have formidable competitors in the United States. But I rely upon the inventive genius, upon the pertinacity of English manufacturers and English scientific men, to secure that we are not to be left behind in that race, the success in which will affect very vitally the interests of the country at large. I hope that science will go hand in hand with industry, and that all those who possess the secrets or can tap the secrets of nature, will assist in the preparations which, it is sad to say, must be made for all eventualities, and in the race for perfection in which we see the other countries so eagerly engaged. Gentlemen, as an unscientific layman, I find a difficulty in picking my words, and walking warily as regards scientific terms. Not long ago I was questioned in the House of Commons with reference to our guns. I had not got the necessary materials at hand for a clear reply, and I walked warily amongst such words as "muzzle velocity," "initial energy," "explosives," and the like. The consequence was that I was charged with having spoken with some hesitation, and the credit of British guns suffered from my want of power of expression. If I seemed to hesitate, it was a hesitation of language, not of conviction. May I commit an outrage—may I speak, not in long detail, but in some detail—on this question of guns to-night? It was a French steel manufacturer, M. Claudinon, whose opinions as to British guns, given to the French Chamber, were brought up against me in the House of Commons. He was produced as a great authority upon guns, but I believe that he has never manufactured a gun, but is an eminent steel manufacturer. M. Claudinon referred to some fleet manœuvres of ours, and spoke of trials of guns, as he represented them to be, which had taken place in June last. But we had no gun trials at that time. What we tried was the rapidity of ammunition supply. M. Claudinon said that the *Mars*, the *Resolution*, the *Hannibal*, and the *Jupiter* tried their new guns. Well, the *Resolution* had no new guns at all, and none tried their

guns. They were simply making quite another experiment. M. Claudinon then stated that in the *Mars* all four guns had their parts started, and it was necessary to reduce the charge, so that the muzzle-velocity should not exceed a certain figure. Not a single gun, not one of those guns had their parts started at all. All this was an entire misconception. Then he said: "In the *Resolution* the two guns of the after-turret and the starboard foremost guns burst." That was utterly untrue. He continued: "In the *Resolution* it was recognised that the muzzle velocity must not exceed 1450 foot-seconds, the maximum safe velocity being 1649." Not at all; some full charges are fired, as you know, and then the charges are reduced, not because the guns are not able to stand them: those guns would stand being fired shot after shot, but in times of peace no nation fires many full charges from guns consecutively, because of the erosive effect. The life of the gun is affected; and the alleged reduction of the charge is simply lowering it to the normal charge which is used in times of peace. M. Claudinon said that the constituent parts of the four 12-inch guns in the *Hannibal* showed signs of parting. Two of the fore and one in the after-turret in the *Jupiter* had to reduce the charge and were unsatisfactory. "Out of sixteen wire guns three have burst and ten have started." The whole story is a fable. Not one single gun has burst, and not one single gun has started. It is in this way that in the eyes of those who believe our foreign critics, the reputation of our guns is destroyed. But, apart from these misstatements, the principal point is this: the charge brought against British guns is that they are deficient in muzzle velocity, and, on that account, they are inferior to the French guns. Can I possibly, after dinner, make it clear what are the factors in the energy of a shot fired from a gun? You know, well enough, as scientific men, that energy depends upon two factors, the velocity and the weight of the projectile; and the consideration of the weight of the projectile has been omitted in the whole of the controversy which has raged with regard to French and British guns. The question is this—a question well known to all artillerists: "Which is better, to have much velocity at the muzzle with a flat trajectory which is its consequence, but with a lighter projectile, or with a smaller velocity but with a projectile which has greater impact when it strikes the object at which it is aimed, and a greater destructive bursting charge?" As we have been reproached for having less velocity at the muzzle than the French, so the French have been reproached by their own people for having so

light a projectile compared with the projectile that we are able to fire at their ships. Our projectile is heavier when it strikes the ship, and our bursting charge is more destructive than that of the French. I will take the latest model of the English 12-inch gun, which corresponds with the French 12-inch gun. The weight of the English shell is 850 pounds; the French shell weighs only 644 pounds. It has a higher muzzle velocity; it goes faster at the beginning, but when it hits it has less weight and less power than our own gun. Our gun is constructed to hit harder than the French gun with a greater bursting charge. From the moment of leaving the muzzle the English projectile commences to be superior to the French as to energy. You all understand that the heavier projectile, as it passes through the air, has a greater power of dividing the air than the lighter projectile, so that when it arrives at the end it strikes the heavier blow. This principle has been adopted deliberately by the British artillerists. As regards the explosive effect of our shell, it is infinitely greater. Of course it is a question of compromise. Now one word as to the French opinion upon this matter. The French are not unanimous with regard to the value of the greater velocity at the muzzle; they say that they regret that they have been hypnotised by the idea of greater velocity. A well-known paper, *La Marine Française*, on January 15, 1900, says: "It will be observed that the English have preferred to make their projectile heavy, regardless of the diminution of their initial velocity; and it is well known, both at home and abroad" (except among some of our critics) "that they have had no reason to regret that decision." That is a French scientific opinion as to the comparison between English and French guns. "The consequence is, according to information derived from the foreign reviews, that the remaining energies are much greater on foreign ships than our own" (that is the French), "and in the remaining energies an enormous amount will depend." The remaining energies will be a great factor at the distance at which torpedoes will compel ships to fight; at that distance the energy of our system will be greater than the energy of the French system. And then the paper continues: "It is no longer a secret that we were wrong in remaining hypnotised, as it were, by the initial velocity idea." We were hypnotised by a different thing, but whether we were hypnotised or not, our gun-makers, our artillerists, and scientific men have probed this matter to the bottom, and they believe that our system is right, and we have been followed in our system by the United States, by Japan, and by other countries. They have followed

our system ; they have increased the weight of the projectile irrespective of the decrease of muzzle velocity. Well, then, the French paper, written by a French critic, says : " It is to be regretted that our Naval Ordnance authorities "—it reads exactly like one of the paragraphs in one of our own papers—" that our Naval Ordnance authorities only met by partial or incomplete proofs these various reproaches, which unfortunately are quite justified by figures and results. They seem to always imagine—the critics—that they are addressing the uninitiated, whether civilian, ministers, or members of Parliament." That is a view that is taken in France. I hope what I have said has shown that, if in this controversy we have adopted a particular principle, we cannot be condemned as having acted carelessly, but have rested upon the best scientific data at our hand. Still we acknowledge that we must not stand still, and we appeal to all those who are able to assist us, whether as regards armour-plates or guns or explosives, that all will place both their scientific and their practical knowledge at the disposal of the Government for the improvement of all our weapons of offence and defence. We do not think that we have reached perfection in any way. We are anxious especially to have the assistance of chemists, of metallurgists, of the scientific men in the country in considering the whole question of our explosives ; and with reference to this I am able to announce that the Government have determined to appoint a committee of scientific men (cheers) to inquire in an absolutely independent way into possible improvements connected with explosives, and I am glad to say that we have secured the services of Lord Rayleigh to be the chairman of the committee (renewed cheers). We wish that that committee should carry out trials with a view to ascertaining what are the best smokeless propellants for use in existing guns of all natures and in existing small arms, and to report whether any modifications in the existing designs of guns are desirable, with a view to developing to the full the powers of any propellant which may be proposed. But do not let it be said that we ask for their advice because we are dissatisfied with the present arrangements. All foreign countries are moving. I believe that Germany, Russia, and France have not got that absolute confidence in their explosives as would remove from them the necessity of inquiring into every improvement that can be brought to bear upon those engines of destruction. Gentlemen, I have spoken upon a technical point, and when we see how in South Africa the question of propellants, the question of velocity, the question of striking energy has come to the front,

and how in any future struggle the safety of our ships, and the lives of our sailors, and the interests of this country would be involved, it behoves not only the Government, but all who in science or in manufactures are able to offer contributions to do their utmost to place in this respect the preparations of the nation on the highest level of manufacture and scientific perfection (cheers).

Major-General F. T. LLOYD, C.B., Governor of the Royal Military Academy, also responded. He said he responded with some diffidence for the service which he had the honour to represent, in that he followed what he might call the most admirable monologue on the science of artillery, delivered by the First Lord of the Admiralty, that he had ever listened to. Speaking of the artillery and the land services, he might tell them as a gunner, and as one in constant communication with officers of all ranks now serving in South Africa, that the artillery were absolutely satisfied with their guns. They would be good enough to remember that a field-gun was a compromise between power and mobility. If they were to have guns possessing great mobility, they could not have them possessing a maximum of striking energy. If they were to have the great striking energy, they must again sacrifice the mobility. That was the mere A B C of the question. They must all of them feel deep gratitude to the navy for having come forward in the way they did at a very critical time in South Africa. But they would also remember that their base was comparatively near, and that they were able to transport medium and even heavy guns to the scene of action without any enormous difficulties. At the same time he thought that they could not be sufficiently thankful to the very able officer who devised the means of mounting the medium gun in such a manner that it could be served on shore. Had they been provided with guns of that nature and calibre, he thought they might have done better than they did. But they did not recognise the necessity for guns of very long range, and that mistake, he thought, was a very excusable one. They were satisfied that they had, for the ordinary ranges of field-artillery, guns capable of competing with any guns in the world. He only wished to point out how deeply the services, and particularly his own branch of the service, was indebted to the gentlemen who formed the bulk of that great Association. They were those whose word went a great way in determining the nature and construction of the guns which were used now or which might have to be used in the future, and he was extremely glad to hear that a Committee was to meet under

such able presidency as had been mentioned by the First Lord of the Admiralty, to try in what way the guns, both of the army and of the navy, could be bettered. It seemed to him to be a common-sense decision at which, if he might humbly say so, the Government had arrived. With regard to the army, more especially the *personnel* of the army, he thought they were all very well satisfied that they had shown themselves brave and courageous soldiers. They had undoubtedly undergone hardships of no common order, and it was to be heartily wished that success might crown Her Majesty's arms in the future, as there was every sign that it was about to do. Above all, they trusted that that gallant force at Mafeking might be speedily released. They who were assembled there that night, enjoying the boundless hospitality of the Iron and Steel Institute, could not help contrasting in their minds the lot of those who were imprisoned in that little place. They trusted that no long period might elapse before an equally bountiful board might be spread before them, that they might no longer live upon horse-sausages and bran-porridge, but that they might be so fortunate as to enjoy the hospitality of this great city and of associations of the nature of the Iron and Steel Institute.

Mr. WILLIAM WHITWELL (Hon. Treasurer) proposed "The Houses of Parliament." In doing so he said he had to speak on a somewhat different topic from those which had so greatly interested them that night, and the topic was one which came home to all English, Irish, and Scotch citizens, and to all who had any sympathy with England, either as regards their business arrangements or their love of their dear country, of which they were so proud. He had to propose for their consideration, and he trusted for their sympathy and approval, "The Houses of Parliament." Many of them knew more about the Houses of Parliament than he did, but he was sure there was no one present who had more sympathy with their work, the object they had in view, and the great ability which was represented by their Members in the Houses of Parliament. He felt that, speaking generally, they had the nation's confidence. England was governed by party, and that was perfectly natural; and it was not singular that it was so, for it was generally the case with all countries in the world. There was not a more honest, a more honourable, a more industrious Legislature than their own. His own feeling was that, if they looked back in history, going back even to the Saxon times, they found that England was striving to be well governed. One great man had said it was the duty of every Christian

citizen to see that his country was well and properly governed. In proposing the toast of the Houses of Parliament, acknowledgment was due for the way in which they legislated. The work that they had done in their respective Houses could never be too fully known. That that work was for their good they were satisfied. The men they had sent to Parliament were doing justice to them, they trusted and believed, and if they thought they were not doing it, they were very quickly willing to make a change. As to the present disastrous war, their conduct spoke volumes for the honour of the country. Looking back at the past in view of the present, they could only say it was wonderful the work that had been performed, and he believed that no war had been conducted in as humane a manner as this had been by English troops. War having been undertaken by this country, the whole question had to be carried through, and the more quickly that was done the better in all respects, both for their name and for themselves, would it be. The loyalty and bravery of those who had gone out we did not dispute. Words failed him to express their splendid endurance and bravery, and, generally speaking, the admirable judgment of their leaders, and finally their magnificent success. He hoped that before very long a crushing blow would be struck at the power of the Boers, which was discreditable to humanity, and discreditable to South Africa and to England too. He coupled the toast with the names of Sir James Kitson, and of Lord Strathcona, who had so liberally come forward in support of the English army in South Africa.

The Right Hon. Lord STRATHCONA, in responding for the House of Lords, said he believed it was admitted on all hands that in the early history of the British Parliament the Peers had well maintained the liberties of the subject, although there were not wanting those who affirmed the House of Lords had outlived its usefulness. Most of them, however, would, he thought, recollect more than one occasion on which the Upper House had done good service to the Empire. At that moment there were with the army in South Africa, representing the old nobility, the Dukes of Norfolk, Northumberland, and Westminster, besides others, and of those more recently admitted as Peers were Lord Roberts and Lord Kitchener, serving under whom were Her Majesty's soldiers, not only from the United Kingdom, but from every portion of the Empire, including Canada, with which he (Lord Strathcona) was more immediately connected. He further mentioned, as intimately associated with the

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work of the Iron and Steel Institute, the honoured names of Lord Kelvin and Lord Armstrong. The House of Lords was not only a legislative body, but had also judicial functions, and they were glad to hear of the proposed Supreme Court, to be strengthened by members from the Colonies, to which all parts of the Empire could appeal with confidence. The past and present usefulness of the House of Lords, he thought, were an earnest of what might be expected from them in the future. In responding to the toast, he might say that he deemed it a compliment to have his name associated with it.

Sir JAMES KITSON, Bart. (Past-President), replied for the House of Commons. He said it had often been his privilege, as an active member of the Institute, to respond to the call of duty and to propose toasts, but he did not know that he had ever had the honour of being called upon to respond for the House of Commons. It might be that that House was suffering from what the First Lord of the Admiralty called erosion, and they might shortly be returned to the laboratory to be re-bored or re-tubed, and it might be that some of them would be found unfit for service and returned to the scrap-heap ; and therefore probably the President had given him the opportunity, for the last occasion, of responding to that toast. He could say, although he was not a member of the predominant party, there were several things on which the vast majority of the House of Commons had been absolutely agreed, and the first was that when that insolent challenge was cast down by the Transvaal and the Free State Governments, and when that invasion of British territory took place, those members of the House of Commons united unanimously in the resolve to take up that challenge and to repel that invasion. To whatever party they might belong, he claimed that they had loyally supported Her Majesty's Government in giving them whatever supplies of men, or money, or material they found it their duty to ask for from the representatives of the nation. He had observed also that those members of the House of Commons who were also members of the Iron and Steel Institute had not been the least eager to assist in voting those supplies, knowing well that those supplies had for the moment promoted the industry on which the defence of the nation at this moment absolutely depended. The House of Commons had been united in its confidence in the administration, and in the talent and capacity which governed Her Majesty's navy. The House of Commons had been absolutely united ; and he did not know that it was revealing any confidence,

that when he heard in the councils of the party of which he was a humble member discussions as to the weak points in the armour of Her Majesty's Government, he had always heard it said that the navy could not be attacked since it was never under the care of a more capable, far-seeing, efficient, loyal, and single-minded man than the present First Lord of the Admiralty. He was proud to respond to the House of Commons, animated as it was with a sense of duty such as had been displayed in those trying moments in the history of the nation, and he believed that the verdict on that House of Commons would be that it had deserved well of the country it represented.

The MASTER-CUTLER OF SHEFFIELD (Mr. R. A. Hadfield) said he had the honour to propose the toast of the "Kindred Societies," coupled with the names of two eminent representatives, the Right Honourable Lord Kelvin and Sir Douglas Fox. He could only say that in Lord Kelvin they had indeed a representative whose name was justly honoured throughout the scientific world. Long might he be spared to them. It was only a few days ago that Lord Kelvin gave a remarkable paper before the Royal Institution in which he had the courage to state that certain important theories, hitherto accepted without question, having been found not to agree with the latest discoveries of science, must be abandoned, no matter how disappointing that might be. He thought a statement like that was the true test of the scientific man. In the President of the Institution of Civil Engineers they had the head of that great Institution, the mother of the technical world, an institution which numbered on its roll-call not far short of 8000 members, and whose hospitality this Institute so truly enjoyed every year. The toast might be dealt with at great length. They had so many technical societies and cosmopolitan bodies and kindred societies from all parts of the world, that it would require a long evening's sitting to do justice to it. But there was at the present time one part of the kindred societies they should remember; he referred to their French members. They had a number of French members on their list who had given admirable papers in the past, and they would like to show how much they appreciated, respected, and admired the energy which had been shown in getting together that magnificent Exhibition in Paris which the Institute was shortly to visit. They all wished hearty success to the Paris Exhibition. He knew that on behalf of the Institute he could express the

best thanks to the kindred societies from which the Iron and Steel Institute derived so much benefit. They as metallurgists were under a heavy debt of gratitude to them, whether on the scientific side of modern technical progress, or what was equally as important to metallurgists—the practical side. Members of the Iron and Steel Institute largely derived their stimulus from these societies, whether the civil engineer, the mechanical engineer, or the naval architect, and, in any case, he thought that they as metallurgists did their utmost to meet their demands. Speaking as head of a very old corporation or guild, the Cutlers' Company of Sheffield, he could only say that his city was doing its best in the defence of the Empire. Sheffield had produced an armour-plate which was absolutely invulnerable, and, of course, had also produced a projectile which would go through any plate. That brought him to another kindred branch, a branch of technical industry, the Royal Engineers in South Africa. They did not hear so much of their doings in the papers, and perhaps the newspaper correspondents did not see so much of them at the front, but they were doing very good work. It was with great pleasure they recognised the assistance that the Royal Engineers were rendering in the country with which they were unhappily at war at the present moment. If a bridge was to be repaired or a kopje to be provided with ammunition, there was the Royal Engineer at hand. He was glad to see a member of a kindred Institute, a well-known technical man, and a man for whom he had a great respect, Major Seymour, of America, who before the war was in charge of the Rand mines at Johannesburg, and now head of one of the corps of Royal Engineers, was now helping the cause of the British Empire. There was much interdependence now-a-days between the various technical societies, and he hoped that the spirit of federating their scientific societies, which was in the air in other directions, would grow, as some of them seemed to overlap in their work. When they had proposed to them such an important federal gathering as that in Paris next September, it showed that perhaps they could work together and bring about a still better condition of affairs. Speaking of kindred technical societies, he could not help referring to Kipling and his admirable sketch of "The Bridge-Builders" in "The Day's Work." This, he thought, showed that the technical man would be more honoured and more recognised in the coming century than he had been in the past. He had much pleasure in submitting the toast of "Kindred Societies."

The Right Hon. Lord KELVIN, in responding, said the British Empire, and he thought he must say the whole of the civilised world, were deeply interested in the work of that Institute and of kindred societies. The whole of science was more or less connected with this toast, and he felt that even with the assistance of Sir Douglas Fox a very heavy burden lay upon him in responding for kindred societies. The greatness of the task was such that it was impossible for him thoroughly and adequately to perform it, and therefore he would make his remarks very short indeed. There were four metals, iron, steel, gold, and lead, all of which were of vital importance to the country. Their President, Sir William Roberts-Austen, represented those four metallic bodies. As President of the Iron and Steel Institute, he represented the working and the wonderful properties of iron in all its combinations, some of them called iron and some of them steel. He did not know if even the members of the Iron and Steel Institute could tell when iron was iron and when it was steel. They wanted good and strong qualities in it, whether it was for rails or railways to help their work in South Africa, or steel plates for the ships that were to carry their soldiers from here to the front, or as near to the front as ships could take them. They were all deeply interested in iron and steel. Gold, he need scarcely say, was the primary sinew of war, and lead they knew was of vital importance just now. The kindred societies included the Royal Society, and the Royal Society to-morrow was to be occupied specially under the guidance of their Chairman with gold and lead together, in connection with his splendid discovery of the diffusion of solid gold into solid lead. He could only say that, with regard to gold and lead and iron and steel, they all looked forward to active and prospering prosecution of this vitally important war. He thought they might even now believe that the time of its end was coming near, and before long they would find right-minded common-sense predominating in South Africa; and that, as part of the British Empire, it would enjoy liberty and peace and prosperity under the beneficent British régime. He thanked Mr. Hadfield, the Master-Cutler of Sheffield, for having so kindly connected his name with the toast, and he thanked all present for the cordial manner in which they had received it.

Sir DOUGLAS FOX, in responding, said he felt it a great privilege that his name should have been coupled with that of Lord Kelvin by the Master-Cutler of Sheffield in the very kind words in which he spoke of

the Institution over which he had the honour to preside. They were proud as an Institution of Civil Engineers to feel that they were in the bonds of closest amity with the members of the Iron and Steel Institute. They were naturally so, because they owed to the members of the Institute so much of the material with which they carried out their designs. Sir Lowthian Bell, their Past-President, had been lately discoursing most charmingly in their Institution about names which were household words to them, and which came to them with great delight—the names, for instance, of Percy, Mushet, Bessemer, and Siemens. As Sir Lowthian Bell spoke to them they were able to realise how true it was that these names had been to a great extent associated with the wonderful growth of their own profession. Therefore, when they welcomed the members of the Institute, as they were glad from time to time to welcome them in their halls in Great George Street (and he hoped they would continue to do so as long as the Institute continued to accept their hospitality), they felt that they were securing assistance which they needed every year of their lives as engineers by having the members of this Institute to help them in their important problems and their difficult questions. He wished specially to say to them that engineers were watching very closely the interesting subject which he believed they had been listening to that day, the microscopic investigation of steel. All those who had had to do with the practical working of steel in connection with railways knew that they had their difficulties, and the members of the Institute were helping them out of those difficulties. He hoped that the result of investigations to be shortly embodied in a report of the Board of Trade Committee might do something in this direction. They had this evening been hearing a great deal about the war in South Africa. Those who had to do with the railways there hoped that the members of the Iron and Steel Institute would help them to rebuild them quickly by giving good deliveries. The Engineers were quite ready, as soon as the Boers would let them do it. They believed that the prospects of that great country could be wonderfully improved by spreading those iron, or rather steel, roads in all directions. Although at the present moment they were not able to do much with the southern part of the Rhodesian system, he was glad to tell them that the companies were doing everything on their part to carry forward the railways to the north and west of Bulawayo. In spite of the war, these works had been going on without interruption. He hoped that the bonds of union between manufacturing and constructing interests would grow in strength and

cordiality. He thanked them very much on behalf of the Institution of Civil Engineers, and he could again assure them that they would be always welcome to the house in Great George Street; and he further hoped that many of them would visit the Guildhall on July 5, when a reception would be held in honour of American engineers then expected in London.

The next toast was "Our Guests," which was to have been proposed by Mr. Andrew Carnegie, who, however, did not arrive till the following day to take part in the meetings of the Institute, and Sir Bernhard Samuelson, Past-President, took his place.

The Right Hon. Sir BERNHARD SAMUELSON, Bart., in proposing the toast, said as the hour was so late, he should employ very few words in submitting the toast to them. He hoped they would believe that that was the sole reason, and that it was not because he undervalued their kindness in being present that evening. They had been most interested in the speech of the First Lord of the Admiralty. It was no part of his duty to comment upon it, or to repeat the expression of their thanks to him. His speech was received with the greatest applause, and would, he was sure, be read to-morrow with the greatest satisfaction in the country. But perhaps they would permit him to say that if the charge which was brought by M. Claudinon in the French Chamber, and by an hon. member, who should be nameless, in our own Parliament, had been brought in the assembly of the Iron and Steel Institute, the apology which the First Lord had found it necessary to make for our guns would not have been required. He was happy to think that although they had many foreign members with whom they associated gladly and with great advantage, M. Claudinon, although he might be an eminent manufacturer of iron and steel, was not a member of the Iron and Steel Institute. Charges of this kind might be expected from a member of the English Parliament unacquainted with their trade, but it did seem a pity that gentlemen connected with the trade were not a little more careful in the statements that they made. These charges would have been very quickly answered if made at one of their meetings. But there was another body, and the President of its Council was with them that evening, a body who might be called the University of the Services. He alluded to the United Service Institution, an institution in which questions of this kind were discussed with knowledge, and whose proceedings were of the greatest interest to the

country. They had the Chairman of that Council with them, and in proposing the health of the visitors he begged to couple with it the name of his old friend and colleague in Parliament, Admiral Sir John Dalrymple-Hay. Sir William Abney's name was also coupled with it. Sir William had done great service to the cause of technical education, and they would do honour to his name in his absence.

The Right Hon. Sir JOHN DALRYMPLE-HAY responded. He said he had a difficult task to perform, but an agreeable one, for he had to return thanks for the guests. He had not the honour of knowing how many guests were enjoying this hospitality, nor had he been elected by the guests to represent them, but he trusted, as he had been nominated for this duty, that they would excuse him if he compressed his remarks into a very short compass, and say how grateful they were all to the members of the Institute for the hospitality with which they had been received. He had known this Institute since its foundation, and he had to dabble in metallurgy in 1854 at the first trial of armour-plates at Portsmouth, before the birth of the Institute. He trusted that all the guests for whom he was returning thanks were very much younger than himself, and that they might live to enjoy for many years to come the Institute's hospitality with all the gratitude which he felt.

The next toast was "Prosperity to the Iron and Steel Institute," proposed by Sir COURTENAY BOYLE, K.C.B., Permanent Secretary to the Board of Trade. He said that all those that were present that night would join with him in heartily drinking prosperity to the Iron and Steel Institute. It was the last toast of the evening, but not the least important. He had often in that room dwelt upon the importance of hearty co-operation between the administrative departments of the State and scientific bodies like their own. He was very glad to think that the importance of that co-operation had been alluded to earlier in the evening by no less an authority than the First Lord of the Admiralty, who told them that an important Committee had been appointed to investigate a very important subject connected with the administration of this country. The Board of Trade was one of the most progressive departments of the State, and he was happy to tell them that they were four years in advance of the Admiralty. They had just received a report from a similar Committee dealing with a very important subject, namely, the construction of steel rails upon our great railways. The Committee was a most important one, and

the investigations of that Committee had led to reports by Sir William Roberts-Austen, by Dr. Thorpe, by Professor Unwin, Professor Dunstan, Mr. Windsor Richards, Mr. Martin, and Sir Lowthian Bell, which would shortly be read with interest and advantage by all of them, and a Report of which the scientific value was only equalled by its practical importance. He did not propose to trouble them at any length with the contents of that Report, which would shortly be in their hands, and in the hands of the public generally. He should like to refer to three important questions connected with the subjects which they had closely at heart. One paragraph was this:—"It is very important that all who are responsible for the manufacture or use of steel rails should realise that steel is not the homogeneous mass it is often supposed to be, but possesses a complex structure. The nature of this structure will vary greatly with the mechanical and thermal treatment to which the metal has been subjected." Next, and this was an important practical recommendation:—"It is very desirable that the mechanical tests to which rails are subjected should be as far as possible standardised in connection with the weight, the section, and the chemical composition of the rail." Very shortly this Report would be in the hands of the railway companies, and he was perfectly sure that the railway companies would do their utmost to give effect to those recommendations, in their own interests and in the interests of the travelling public. The next and the only other section to which he would refer was this:—"With these conclusions the Committee agree, and as regards chemical composition they do not think it desirable to insist upon too high a proportion of carbon, manganese, or silicon in the steel, having regard to the ordinary contingencies of manufacture and the great susceptibility of high carbon steel to thermal influences." The Report, as he had said, would be of great practical value. It had great scientific value also, but above all it emphasised the importance in practical administration of scientific research, and he could not help expressing the hope that the great masters of the iron and steel industry would use their unrivalled talents in the perfection and the development of scientific research, because he was perfectly certain that in that they would conduce most not only to their commercial advantage, but to the welfare and prosperity of the community at large. He drank to the health of the Iron and Steel Institute, and coupled the toast with his old friend, their Chairman, Sir William Roberts-Austen. With his metallurgical and scientific qualities they were better acquainted than himself, but

he could assure them of his absolute conviction, which he supposed they would justify very shortly, not only that he was a jolly good fellow, but an exceedingly good administrator also.

The PRESIDENT, in acknowledging the toast, said that at that very late hour he should earn their gratitude by replying in the fewest possible words, though the brevity of the speech must not be taken as a measure of his gratitude. He should always be proud to remember that he presided over that great Institution at a time of exceptional national difficulty. There was one point to which he wished to refer, and that was the absence of Mr. Andrew Carnegie that night. They had hoped, now that the bonds between England and America were so close, to have heard his voice that evening ; but unfortunately the ship which was to have arrived at nine o'clock that morning would not arrive until nine o'clock the following morning, when they might hope to see Mr. Carnegie at the Institute meeting, though it was too late for his presence that evening. He felt very grateful indeed for the extremely kind way in which Sir Courtenay Boyle had referred both to the Institute and to himself. Might their Institute prosper in the years to come as it had in the past; that was his fervent wish.

The proceedings then terminated.

OBITUARY.

ARTHUR ALBRIGHT, of Mariemont, Birmingham, died suddenly on July 3, 1900, in London, at the residence of his son-in-law, Sir C. C. Scott-Moncrieff, at the age of ninety years. He was the senior partner in the firm of Albright & Wilson, of Oldbury, phosphorus manufacturers. In former years he took a very active part in the industrial and social affairs in the Birmingham district, but a severe attack of influenza in 1898 necessitated his removal to London, to be near his medical adviser. He was elected a member of the Iron and Steel Institute in 1875.

WILLIAM DUFF BRUCE died suddenly at his residence in London on April 28, 1900. He for many years took a large share in the development of Indian railways, of several of which he was for a number of years London representative. He also represented the Bengal Iron and Steel Company, the owners of the Barrakur Ironworks, India. He was well known and highly esteemed in the engineering profession. He was deputy-chairman of the Rio Tinto Company, Limited. He was a member of the Institution of Civil Engineers and of the Institution of Mechanical Engineers, and was elected a member of the Iron and Steel Institute in 1890.

JAMES MACALLUM CHERRIE died suddenly at his residence, Clutha Cottage, Tollcross, near Glasgow, on March 9, 1900. He commenced his business career in the office of the Blochairn Steelworks, Glasgow, and later entered the service of Messrs. Beardmore at the Parkhead Forge. A few years later he was appointed general commercial manager of that firm, which position he held until 1887. In that year he began business for himself as an iron and steel merchant, which he carried on successfully for some time; but he was less fortunate during later years. He was a member of the Glasgow Philosophical Society for many years, and was well known and greatly respected in Glasgow business circles. He was elected a member of the Iron and Steel Institute in 1883.

JOHN CRAVEN died at his residence, Smedley Lodge, Cheetham, near Manchester, on June 12, 1900. He was a member of the firm of Craven Brothers, toolmakers and machinists, Manchester, and was well known throughout the Manchester district. He was closely associated with the industrial, municipal, and educational affairs of Manchester, and took a very active part in the technical education schemes of the city. In 1897 he was appointed one of the deputation who visited Germany and Austria to report upon the technical educational institutions of those countries, with a view to introducing the best methods in the equipment of the Manchester Technical School. He also took a large share in organising the Machinery Section of the Royal Jubilee Exhibition. He served as president of the Manchester Association of Engineers. He was elected a member of the Iron and Steel Institute in 1887. He attended the meetings with regularity, and took part in the reception of the Institute at its meeting in Manchester in 1899.

BERNARD DAWSON died, at the age of fifty years, on March 3, 1900, at his residence, The Laurels, Malvern Link, after a long illness. He was one of the leading authorities on blast-furnace and open-hearth practice, and had a considerable practice as an iron and steel works expert. He was a well-known figure at the meetings of the Iron and Steel Institute, and frequently took part in its proceedings. He also took an active part in organising the Birmingham meeting of the Institute in 1895. He was a member of the Institution of Mechanical Engineers, and was elected a member of the Iron and Steel Institute in 1883.

GÖRAN FREDRIK GÖRANSSON died at Sandviken, Sweden, on May 12, 1900, at the age of eighty-one. Without his aid the Bessemer process might perhaps never have been perfected. In 1858, at Edsken, he increased the area of the tuyeres, and succeeded in shortening the process so as to produce sufficient heat in the converter to allow of the proper separation of the slag from the metal, and to convert pig-iron into good steel, which, having been exported to England, encouraged the capitalists who were supporting Sir Henry Bessemer. Mr. Göransson was chairman of the board of directors and founder of the Sandvik Ironworks. His great services to metallurgy were recognised by numerous honours conferred upon him. In 1865 he received the great gold medal of the Jernkontor. He was a Knight Grand Cross

of the Royal Wasa Order, and a Knight of the Royal Order of the Polar Star. He was a member of the Swedish Academy of Sciences, and a few days before his death he was appointed Doctor of Philosophy *honoris causa* of Upsala University. At the Swedish meeting of the Iron and Steel Institute in 1898, Mr. Göransson, although very infirm, welcomed the members in an English speech to the Sandvik Works.

ALFRED HILL died in April 1900 at his residence at Coatham-by-the-Sea, at the age of forty-six years. He was managing director of Richard Hill & Company, Limited, of the Newport Wireworks, Middlesbrough. He was elected a member of the Iron and Steel Institute in 1890.

SAMSON JORDAN died on February 24, 1900, at the age of sixty-nine. Born at Geneva on June 23, 1831, he entered the Ecole Centrale in 1851, and left with great distinction in 1854. For several months he was employed by the Northern Railway Company of France, and in 1855 he was entrusted with the erection of the Saint-Louis blast-furnace by the Société de l'Eclairage au Gaz et des Hauts-Fourneaux de Marseille. On the completion of this work he became assistant-manager of the Company at Marseilles. In 1862 he was appointed consulting engineer to the Company and proceeded to Paris. In 1873 he became general manager, and remained director of the Company until his death. In 1863 he was appointed lecturer in metallurgy at the Ecole Centrale, and in 1865 became Professor and Member of the Council of the School. He was also a director of the Denain and Anzin Works, and of the Compagnie Franco-Belge des Mines de Somorrostro. He was president of the Society of Civil Engineers of France in 1874. He had also been president of the Gas Institute of France, and at the time of his death was vice-president of the Comité des Forges of France. At various exhibitions he was called upon to fill important posts that showed the confidence inspired by his wide experience and clear views. In 1878 he was vice-president of the International Jury; in 1889 he was president of the Jury of Class 48; and lastly, he was reporter of Class 64 at the Exhibition of 1900. He was a member of Council of the Société d'Encouragement pour l'Industrie Nationale. Numerous high honours were bestowed upon him in appreciation of his great services to metallurgy. He was an Officer of the Legion of Honour, Officer of Public Instruction, Commander of the Order of Isabella the Catholic, Knight of the Order of the

Polar Star of Sweden, and Commander of the Order of Merit of St. James of Portugal. He was the author of numerous works on metallurgy, including the standard treatise on the subject, published in 1871. He also published an important work on spiegeleisen and its manufacture, which was introduced at Saint-Louis in 1864. The numerous monographs from his pen dealt with the manufacture of steel, with the calorific theory of the Bessemer process (1869), with the manufacture of cannons and projectiles, and with the roasting of iron ore at Bilbao. He was elected a member of the Iron and Steel Institute in 1874. He contributed papers to its proceedings in 1878 and in 1889, was a frequent contributor to the discussions of papers read, and was an energetic member of the Reception Committee on the occasions of the Paris meetings of the Institute in 1878 and in 1889. At Professor Jordan's funeral on February 28, eloquent speeches were delivered by Mr. C. Baudry in the name of the Society of Civil Engineers of France, by Mr. L. E. Deharme in the name of the Ecole Centrale, by Mr. H. Germain in the name of the Marseilles Company, by the Baron de Nervo in the name of the Comité des Forges, by Mr. A. Carnot in the name of the Société d'Encouragement, by Mr. T. Vautier in the name of the Gas Institute, by Mr. C. Balsan in the name of the old students of the Ecole Centrale, and by Mr. L. Feray in the name of the graduates of 1854 of the Ecole Centrale. Eloquent testimony was thus afforded to the value of Professor Jordan's work and to the esteem in which he was held.

CARL CARLSON LINDBERG died on February 12, 1900. He was born on July 30, 1851, at the Carlsdahl Ironworks, Karlskoga, Sweden, works purchased by his grandfather in 1824. His father, Carl Lindberg, who was one of the leading ironmasters of his time, did much to develop the Carlsdahl works, and introduced there in 1862 the Bessemer process, the second plant erected in Sweden. Carl Carlson Lindberg profited by the training he received from his eminent father. He was educated at Gothenburg and at the Stockholm School of Mines. After a varied experience in iron ore mining, he was in 1883 appointed manager of the Laxå Works, which under his charge developed in a remarkable manner. He was a member of Council of the Swedish Association of Ironmasters, and was elected a member of the Iron and Steel Institute in 1888. He was one of the five members of the Executive Committee that arranged the reception of the Institute in Stockholm in 1898, and he hospitably entertained the members of the Western Excursion at Laxå Works.

WILLIAM MCCOWAN died in March 1900 at his residence, Roseneath, Whitehaven, at the age of sixty-two years, after an illness of about two months' duration. He was chairman of the Whitehaven Hæmatite Iron and Steel Company; of the Distington Iron Company; of the Moss Bay Iron and Steel Company; and a director of the Elliscales Mining Company; of the Cleator and Workington Junction Railway Company; and of the Barrow Saltworks Company. He took a leading part in the industrial, political, and social affairs of West Cumberland, and was a Justice of the Peace for the county. He was elected a member of the Iron and Steel Institute in 1884, and regularly attended its meetings.

HENRY PERSEHOUSE PARKES died very suddenly at Malvern on May 17, 1900, at the age of sixty-eight years. He was the head of the firm of Henry P. Parkes & Company of Tipton, chain, anchor, and cable manufacturers; director of the Staffordshire Proving House Company; director of Rollason & Company, wiredrawers, of Birmingham; and a member of the employers' section of the Chain and Anchor Wages Board. He was well known in Staffordshire and Birmingham business circles, and took an active part in the commercial and social affairs of the district. He was a prominent member of the Dudley Chamber of Commerce, and was a Justice of the Peace for the county of Stafford. By his will, after providing for relatives, he left the residue of his estate to found the "Persehouse Pensions for aged and distressed persons of the middle and upper classes resident for ten years in the counties of Stafford and Worcester." He was elected a member of the Iron and Steel Institute in 1882.

GUSTAVE ERNEST POLONCEAU, who died early in 1900, was born on March 3, 1832. On leaving the Paris School of Mines in 1854, he served his time in the workshops of the Orleans Railway Company, of which his relative, Camille Polonceau, was then chief engineer. He soon became inspector, and subsequently assistant locomotive superintendent on the second section of the line. In 1870 he was appointed chief inspector of the Imperial Turkish Railway, and in 1871 received the star of Officer of the Medjidîé. In February 1872 he was appointed chief engineer on the Austrian State Railway. Sent on an official mission to Roumania, he was appointed on April 1 director of the Roumanian Railways, and a large amount of railway construction was carried out under his direction. He then returned to Vienna, and in

1877 received the Cross of the Iron Crown in recognition of his labours in organising the service of transport of wounded. In the same year he was appointed a Knight of the Legion of Honour, and in 1895 was promoted to be Officer of that Order. He remained in Austria until December 1885, when he returned to the Orleans Company as chief engineer. He introduced a number of important improvements and numerous valuable inventions of his own. He was president of the Society of Civil Engineers of France in 1891, and took part in a number of technical commissions, notably the Commission on Methods of Testing of the Metallurgical Section, of which he was vice-president. He was elected a member of the Iron and Steel Institute in 1890, having previously, as vice-president of the Society of Civil Engineers of France, taken an active part in organising the Paris meeting of the Institute in 1889.

HENRY HYAM RIDER died in March 1900 at his residence, Elmfield House, Rotherham, at the age of forty-three years. He began his business training at the Darlington Waggon and Engineering Works. On leaving Darlington, he entered the service of Messrs. Harrison & Camm, waggon builders and engineers, of Rotherham, with whom he was associated for about twelve years. At the time of his death he was managing director of the firm. He was elected a member of the Iron and Steel Institute in 1894.

JAMES SAUNDERS died at his residence, Wolverhampton, on April 13, 1900, at the age of sixty-eight. He was for some years the South Staffordshire representative of Newton, Chambers & Co., of Sheffield. He had been connected with the iron trade for about thirty-five years, prior to which he was a law-stationer. He took an active part in the municipal affairs of Wolverhampton, and served as Alderman and Mayor of the borough. In 1898 he retired from the Council, when a vote of thanks for his seventeen years of useful service, engrossed on vellum, was presented to him. He was also a Justice of the Peace. He was elected a member of the Iron and Steel Institute in 1887.

JOHN SMETHURST died at his residence, Landgate House, Brynn, near Wigan, in March 1900, at the age of fifty-two years. He was the second son of the late John Smethurst, of Blackrod and Southport, colliery owner, and began his professional career at the Scot Lane Collieries of William Woods & Son, of which collieries his father had charge.

Later on he joined the firm of Dewhurst, Hoyle & Smethurst, of which his father was managing partner, and on the transfer of the business to the Garsewood Hall Colliery Company, Limited, he became general manager, a position he held at the time of his death. He was elected a member of the Iron and Steel Institute in 1895.

EDMUND GEORGE TOSH died at his residence, The Lund, Ulverston, after a very short illness, on April 22, 1899. The son of George Tosh, of Scunthorpe, near Doncaster, he was born at Parton, near Whitehaven, in 1847, and was educated at Glasgow University and at Göttingen, in Germany. He obtained the degree of M.A. and Ph.D. at the age of twenty-one years, and afterwards practised as an analytical chemist in West Cumberland, where he had a high reputation. Subsequently he was appointed general manager of the Solway Hæmatite Iron Company at Maryport, and in 1876 general manager of the North Lonsdale Iron and Steel Works, a position which he held up to the time of his death. During the twenty-three years of his management not a single strike or lock-out occurred at the works, and he was greatly esteemed by every one with whom he was connected. He was closely associated with the political, municipal, and social life of Ulverston and district, and as a member of the local authority he exercised a large influence on the affairs of the town for an unbroken period of twenty-two years. He was also Captain of the local Volunteers for several years. He was a Fellow of the Chemical Society, and was elected a member of the Iron and Steel Institute in 1870. He regularly attended the Institute's meetings, and frequently took part in its proceedings.

ADDITIONS TO THE LIBRARY

DURING THE FIRST HALF OF 1900.

Title.	By whom Presented.
"On the Prevention of Eye Accidents Occurring in Trades." By Simeon Snell. London. 1899.	The Publishers.
"Annual Report of the Chief of the Bureau of Steam Engineering for 1899." Washington. 1899.	The Bureau.
"Le Cinquantenaire de l'Union des Ingénieurs et Architects d'Autriche." By A. Jacqmin. Paris. 1899.	The Author.
"The Report on the Concessions of the Pekin Syndicate in the Provinces of Shansi and Honan." By J. G. H. Glass.	The Pekin Syndicate.
"American Commerce, with Share of the United States and other Leading Nations therein." 1821-1898.	The Philadelphia Commercial Museum.
"Exports of the Products of Domestic Manufacture from the United States." 1889-1898.	The Philadelphia Commercial Museum.
"Eighth Supplement to the Register of the British Corporation for the Survey and Registry of Shipping." December 1899.	The Corporation.
"Engineers and their Institutions." By J. W. Howard. Gloucester. 1899.	The Author.
"Mines and Quarries: General Report of Statistics for 1899. Fatal Accidents and Deaths in and about the Mines and Quarries of the United Kingdom."	The Under-Secretary of State.
"Ausführliches Handbuch der Eisenhüttenkunde." By Dr. Hermann Wedding. Brunswick. 1900.	The Author.
"Californian State Mining Bureau." Bulletins 13 and 14.	The Bureau.

Title.	By whom Presented.
"The Production of Manganese Ores in 1898." By John Birkinbine. Washington. 1899.	The Author.
"The Characteristics and Conditions of the Technical Progress of the Nineteenth Century." By James Douglas. New York City. 1900.	The Author.
"Centrifugal Ventilators." By J. T. Beard. Reprinted from <i>Mines and Minerals</i> , September, October, and November 1899. Scranton, Pennsylvania. 1900.	The Editor of <i>Mines and Minerals</i> .
"Mesure des Températures Elèves." By H. Le Chatelier and O. Boudonard. Paris. 1900.	The Authors.
"Calendar of the University College of South Wales and Monmouthshire." 1899-1900. Cardiff. 1899.	The University.
"Industrial Importance of the Process of Magnetic Separation." Invented by J. P. Wetherill. Frankfort. 1899.	The Publishers.
"The British Corporation of the Survey and Registry of Shipping." New Rules for Shafting. Glasgow. 1900.	The Corporation.
"Annual Catalogue of the Purdue University." 1898-1899. Indianapolis. 1899.	The University.
"Des Associations de Propriétaires d'Appareils à Vapeur, Compte Rendu des Séances du 15, 20, 21, 22, 23 Congrès des Ingenieurs en Chef."	The Director.
"Mines and Quarries: General Report of Statistics for 1899."	The Under-Secretary of State.
"The Bulletin of the Geological Institution of the University of Upsala." Nos. 1-7. 1892-1898.	The Librarian.
"The Redruth School of Mines Syllabus for 1900-1901." Redruth. 1900.	The Registrar.
"Annealing Malleable Cast Iron." By George C. Davis. Easton, Pennsylvania. 1900.	The Author.
"Sixteen Pamphlets."	The Secretary of the Sociétés Reunies des Phosphates-Thomas.
"The Insurance Register for 1900." London. 1900.	Messrs. C. & E. Layton.

Title.	By whom Presented.
"Mines and Quarries: General Report and Statistics for the Year 1898." Part IV. Colonial and Foreign Statistics. London. 1900.	The Under-Secretary of State.
"On the Manufacture of Steel on the Basic Open-Hearth." By Thomas Turner of Kilmarnock. Glasgow. 1900.	The Author.
"Foundry Iron." By H. Pilkington.	The Author.
"Guide through the Stora Kopparbergs Bergslags Aktiebolags Exhibition at Paris." 1900.	The Secretary.
"George Cradock & Company's Catalogue of Steel Wire Ropes." London. 1900.	The Company.
"The Exhibition of Chased and Embossed Steel and Iron Work of European Origin." London. 1900.	The Secretary, Burlington Fine Arts Club.
"L'Utilisation des Gaz de Haut-Fourneau dans les Machines." By E. Demenge. Nancy. 1900.	The Author.
"Les Plaques de Blindages. By L. Baclé. Paris. 1900.	The Publishers.
"Dritter Nachtrag—Katalog der Bibliothek des Königlichen Technischen Hochschule zu Aachen. Aachen. 1900.	The Librarian.
"The Presidential Address of D. M. Nesbit, read before the Institution of Heating and Ventilating Engineers." London. 1900.	The Institution.
"Engelska Stenkol." By A. Wahlberg. Stockholm. 1900.	Professor H. Louis.
"Annual Statistical Report of the American Iron and Steel Association for 1899." Philadelphia. 1900.	J. M. Swank.
"Californian State Mining Bureau." Bulletin No. 17.	The Secretary.

INSTITUTIONS.

The Publications of the Institute are exchanged for those of the following Institutions :—

LONDON.

Board of Trade.
 British Fire Prevention Committee.
 Chemical Society.
 City and Guilds Institute.
 Geological Society.

H.M. Patent Office.
 Imperial Institute.
 Institution of Civil Engineers.
 Institution of Electrical Engineers.
 Institution of Mechanical Engineers.
 Institution of Mining and Metallurgy.
 Institution of Naval Architects.
 Royal Artillery Institution.
 Royal Institute of British Architects.
 Royal Institution.
 Royal Society.
 Royal Statistical Society.
 Royal United Service Institution.
 Society of Arts.
 Society of Chemical Industry.
 Society of Engineers.
 University College.

PROVINCIAL.

Cleveland Institution of Engineers.
 Engineering Society (Leeds).
 Hull and District Institution of Engineers.
 Institution of Engineers and Shipbuilders in Scotland.
 Liverpool Engineering Society.
 Liverpool Polytechnic Society.
 Manchester Association of Engineers.
 Manchester Geological Society.
 Mason College (Birmingham).
 Merchant Venturers' Technical College (Bristol).
 Mining Institute of Scotland.
 North-East Coast Institution of Engineers.
 North of England Institute of Mining and Mechanical Engineers.
 Royal Dublin Society.
 Sheffield Technical School.
 South Staffordshire Institute of Iron and Steel Works Managers.
 South Staffordshire Ironmasters' Association.
 South Wales Institute of Engineers.
 University College of South Wales.
 West of Scotland Iron and Steel Institute.

COLONIAL AND FOREIGN.

Colonial.

Canadian Institute.
 Canadian Mining Institute.
 Canadian Society of Civil Engineers.
 Department of Mines, Sydney.
 Department of Mines, Melbourne.
 Geological Survey of Canada.

Geological Survey of India.
Geological Survey of New South Wales.
Mining Society of Nova Scotia.
Royal Society of New South Wales.

United States.

Alabama Industrial and Scientific Society.
American Association for the Advancement of Science.
American Institute of Mining Engineers.
American Iron and Steel Association.
American Society of Civil Engineers.
American Society of Mechanical Engineers.
Department of Labour.
Engineers' Society of Western Pennsylvania.
Franklin Institute.
New York Academy of Sciences.
Ordnance Office, War Department.
School of Mines, Columbia College, New York.
Smithsonian Institute.
United States Geological Survey.

Austria.

K. k. geologische Reichsanstalt.
Oesterr. Ingenieur- und Architekten-Verein.

Belgium.

Association des Ingénieurs sortis de l'Ecole des Mines de Liège.
Ministère de l'Interieur.

France.

Comité des Forges.
"Revue Maritime." Ministère de la Marine.
Société d'Encouragement pour l'Industrie Nationale.
Société de l'Industrie Minérale.
Société des Anciens Élèves des Écoles Nationales d'Arts et Métiers.
Société des Ingénieurs Civils.
Société Scientifique Industrielle de Marseille.

Denmark.

Tekniske Foreningen.

Germany.

Königliche Bergakademie in Freiberg.
Königliche Technische Versuchsanstalt.
Verein Deutscher Eisenhüttenleute. (Journal "Stahl und Eisen.")
Verein Deutscher Ingenieure.

Italy.

Reale Accademia dei Lincei.

Sweden.

Jernkontoret.

JOURNALS.

The following periodicals have been presented by their respective Editors:—

UNITED KINGDOM.

- "British Trade Journal."
- "Coal and Iron."
- "Commerce."
- "Contract Journal."
- "Colliery Guardian."
- "Electrician."
- "Electrical Engineer."
- "Engineer."
- "Engineer and Iron Trades' Advertiser."
- "Engineering."
- "Engineers' Gazette."
- "Hardwareman."
- "Hardware Trade Journal."
- "Industries and Iron."
- "Invention."
- "Iron and Steel Trades' Journal."
- "Iron and Coal Trades' Review."
- "Ironmonger."
- "Ironmongery."
- "Iron Trade Circular."
- "Machinery Market."
- "Marine Engineer."
- "Mechanical Engineer."
- "Phillips' Monthly Register."
- "Plumber and Decorator."
- "Practical Engineer."
- "Railway Engineer."
- "Railway World."
- "Science and Art of Mining."
- "Shipping World."
- "Statist."
- "Steamship."
- "The London Technical Education Gazette."
- "Tool and Machinery Register."

COLONIAL AND FOREIGN.**Colonial.**

- "Canadian Mining Review."
- "Indian and Eastern Engineer."
- "Indian Engineering."

United States.

- "Age of Steel."
- "American Journal of Science."

- "American Manufacturer."
- "Bradstreet's."
- "Cassier's Magazine."
- "Engineering and Mining Journal."
- "Engineering Magazine."
- "Engineering News."
- "Iron Age."
- "Iron Trade Review."
- "Letter of the Anthracite Coal Operators' Association."
- "Metallographist."
- "Mines and Minerals."
- "Railroad Gazette."
- "Report of Proceedings of the Master Car Builders' Association."
- "Tin and Terne."

Austria.

- "Allgemeine bergmännische Zeitschrift."
- "Oesterr. Zeitschrift für Berg- und Hüttenwesen."

Belgium.

- "Bulletin de l'Union des Charbonnages de Liège."
- "Moniteur des Intérêts Matériels."
- "Revue Universelle des Mines."

France.

- "Annales des Mines."
- "L'Echo des Mines."
- "Le Génie Civil."
- "Le Mois Scientifique et Industriel."
- "Portefeuille Économique."

Germany.

- "Annalen für Gewerbe und Bauwesen."
- "Chemiker Zeitung."
- "Glückauf."
- "Verein Deutscher Eisen und Stahl Industrieller."
- "Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate."
- "Zeitschrift für praktische Geologie."
- "Zeitschrift für Werkzeugmaschinen und Werkzeuge."

Italy.

- "L'Industria."
- "Rassegna Mineraria."

Spain.

- "Revista Minera."

Sweden.

- "Teknisk Tidskrift."

SECTION II.

NOTES ON THE PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

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In the preparation of these Notes the Editor has been assisted by E. J. BALL, Ph.D.,
and H. G. GRAVES, Assoc. R.S.M.

IRON ORES.

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I.—OCCURRENCE AND COMPOSITION.

Genesis of Ore Deposits.—C. R. van Hise * discusses the principles controlling the deposition of ores, referring to the action of ascending and descending currents of water, cross currents, cross joints, and fractures. Special stress is laid on the fact that hardly any ore deposit presents a simple problem with respect to its origin or distribution, and it seems to be clear that there are many different factors at work on even the simplest deposit. Three groups of ore deposits are distinguished: those made by ascending waters, those made by descending waters, and those due to ascending and descending currents combined. The paper led to much discussion, and the views of Posepny and others were referred to.

J. F. Kemp † has issued the third edition of his work on ore deposits, dealing with their origin and generation. Numerous additions to and alterations of the earlier editions are made.

G. Gürich ‡ deals with the genetic classification of ore deposits.

Phosphorus in Iron Ore.—The following comparative statement

* *Transactions of the American Institute of Mining Engineers, Washington Meeting, February 1900.*

† "Ore Deposits of the United States and Canada," 8vo, 3rd edition, pp. 481. New York, 1900. Scientific Publishing Co.

‡ *Zeitschrift für praktische Geologie*, 1899, pp. 173–176.

has been published* showing the percentage of phosphorus in the principal iron ores used for metallurgical purposes:—

	Phosphorus per Cent.	Iron per Cent.
North of Spain—		
Navarre	0·0 to 0·002	52 to 55
Bilbao-Campanil	0·013	54·90
South of Spain—		
Sierra de Aulargo	0·007	61·2
Sierra de Layon	0·03	62·6
Emiliano	0·016	61·3
Other mines	0·004	62·5
Sierra Nevada	0·055	58·0
Algeria	0·011	58 to 62
Island of Elba—		
District of Rio	0·17	61·81
Other mines	traces to 0·008	58 to 62
Russia—		
Wissokaia (Ural)	0·02	63·69
Blagodai . . . . .	...	55·0
Puchia	1·00	50·0
Sweden—		
Gellivaare	0·10	65·0
Luossavaara	0·01 to 0·08	68 to 71
Kiirunavaara	0·03 to 2·8	61 to 72
Norway—		
Trondhjem	0·08 to 0·26	46 to 58
Nissedal	1·75 to 2	50 to 60
Tomo	0·208 to 0·15	43 to 63
United States—		
Marquette	0·030 to 0·051	43·5 to 67·74
Canada—		
Ontario	trace to 0·026	58 to 65
Quebec	0 to 0·008	63 to 68
Nova Scotia—		
Londonderry	0·37 to 0·08	58 to 60
Pictou	0 to 0·02	57 to 65
India—		
North-West Provinces	0·013 to 0·5	60 to 75
Central	0 to 0·005	60 to 71
Madras	traces	65 to 70

Iron Ore in Austria.—J. Lowag † traces the history of the iron ore mining industry in the Altvater Mountains, going back to the time of the Romans. At the present time no iron mine is in operation. The deposits which might advantageously be worked are the magnetites at Alt-Hackelsberg, near Niedergrund, Austrian Silesia, the magnetites and red hæmatites of Neuvogelseifen, near Kleinmohrau

* *Revue Universelle des Mines*, vol. xlvii. pp. 264-300.

† *Allgemeine Bergmännische Zeitschrift*, March 1, 1900, pp. 27-30.

railway station, the magnetites and red hæmatites of the Mohrau Forest and Bräunelstein, also near Kleinmohrau, in Austrian Silesia, and several other deposits in the district in Austrian Silesia and in Moravia.

Iron Ore in Hungary.—Rich iron and manganese ore deposits have been discovered in South Hungary, at Pojen, in the Krasso Szöreny county. There are three principal occurrences in the district. In the first case, specular iron ore, containing 60 to 70 per cent. of iron, is met with in two veins 3 to 6 feet thick, which can be followed by quarrying for several hundred yards. In the second case, a massive deposit of red hæmatite has been found. Lastly, there is a vein of iron ore 6 feet thick, the ore yielding 50 per cent. of iron.*

Iron Ore in Normandy.—In Normandy the iron ore deposits are deserving of attention. The ore is mostly a hard, compact, rich hæmatite. The deposits were worked in former times, but the two forges at Balleroy and Danvou extinguished their fires at the end of the eighteenth century. At the present time the deposits are for the most part unworked. Of late years, however, although foreign pig iron is imported for local consumption, cargoes of iron ore have been sent from Caen to England and Germany. The ore was raised from the ancient "Fosses d'Enfer" (probably a corruption of "fosses en fer") in the Saint-Rémy mountain. Quite recently a similar deposit has been found at May on the banks of the Orne, the ore being carried down to the railway on an aerial railway. The Saint-Rémy ore contains 57·83 per cent. of iron and 0·11 per cent. of phosphorus. The percentage of sulphur never exceeds 0·18.†

Iron Ore in Algeria.—Poncelet ‡ gives the results of analyses of Algerian iron ore, some of which appear to be of excellent quality. A brown hæmatite from Bab-M'Teurba gave 55·87 per cent. of iron, 4·5 per cent. of manganese, and no phosphorus. A specimen from Dar-Rih yielded 63·67 per cent. of iron, 1·75 per cent. of manganese, and no sulphur or phosphorus. Specular iron ore from Djebel-Hamman near Melilia in Morocco gave 67·89 per cent. of iron.

* *Industrielle Nachrichten*, November 11, 1899.

† *La Revue Minière Illustrée*, May 5, 1900.

‡ *Annales des Mines*, vol. xvi. p. 221.

Iron Ore in Lorraine.—Rick* traces the development of the mining industry of Lorraine. In a few years the pig iron production of Germany will be equal to that of Great Britain. This result, which was not dreamt of twenty-five years ago, is chiefly due to the iron ore resources of Lorraine. The iron ore production of that State represents more than a half of all the iron ore raised in Germany, and is based on the occurrence of the so-called minette, an oolitic brown iron ore, extending from the Grand Duchy of Luxemburg along the left bank of the Moselle as far as Nancy. Owing to its high percentage of phosphorus, which makes the iron brittle, this minette was formerly an ore of little value. Twenty-one years ago the basic method of making steel was introduced, and this revolutionised the iron trade and rendered the minette deposits of vast importance for the German iron industry. The importance of this invention to Germany is shown by the fact that at the present time that Empire furnishes two-thirds of the world's supply of basic steel, and that chiefly from the ores of Lorraine. It must also not be forgotten that the slag obtained, owing to its high percentage of phosphorus, is an excellent fertiliser for agricultural purposes, so that many thousands of pounds formerly going abroad now stay in Germany. The rapidity of the development of Lorraine is shown by the following figures :—In 1872 the total output of iron ore was 365,000 tons, valued at £40,000; the present output is 6,000,000 tons, valued at £700,000, or in other words, sixteen times as much. According to the latest calculations, there are in Lorraine 2000 million tons of workable ore still untouched.

Iron Ore in Germany.—The Bautenberg Company of Düsseldorf has struck some excellent iron ore at the 100-fathom level of the Bautenberg shaft. The vein is 2 yards thick and is still untouched in the upper levels.†

J. von Remmelen‡ discusses the occurrence, composition, and mode of formation of the iron ore met with in peat moors, dealing especially with that portion of the Drenther Moor which is known as Emmer Compascuum. Here amorphous ferrous carbonate is found together with some crystalline carbonate. Analytically the mass is found to consist of 80 to 90 per cent. ferrous carbonate, 3 to 6 per cent. calcium carbonate, 7 to 8 per cent. of vegetable matter, about 0·2 of

* *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. pp. 1367-1369.

† *Industrielle Nachrichten*, April 30, 1900.

‡ *Zeitschrift für Anorganische Chemie*, vol. xxii. p. 315.

phosphoric acid, and under 1 per cent. of sulphuric acid, magnesia, and alkalies. Crystalline ferrous carbonate is found by itself, but is never free from the amorphous form, vivianite, or vegetable matter. It does not further oxidise when exposed to air.

The author considers that the iron ore now found in the moor came from water which passed from the diluvium on which the peat rests into the peat, gave up its carbon dioxide, and so deposited the iron which had existed in it in solution. The ore occurs finely disseminated, but in places lenticular bodies of it are found of some size, the largest yet met with being some 46 feet long, 20 feet broad, and 20 inches in thickness.

Magnetite from near Rome.—F. Zambouini * gives a description of the fine crystals of magnetite occurring in lava at the quarries of Aquacetosa and Tavolato, near Rome. Analyses of grains (I.) and of crystals (II.) gave the following results :—

	Fe ₂ O ₃ .	FeO.	TiO ₂ .	MgO.	Total.
I.	69.5	28.7	0.9	0.7	99.8
II.	70.2	28.9	0.6	0.7	100.4

Iron Ore in Portugal.—In a French Consular Report, G. Outrey describes the mining industries of Portugal. Iron ore occurs in abundance. The deposits are of considerable thickness and easily mined. Coal is also met with at the San Pedro da Cova and at the Cabo Mondego. In former times the metallurgical industry of Portugal was of considerable importance. From 1450 to 1615 iron-works were very prosperous, using Portuguese ore, and in view of the fact that the country possesses iron ore, coal, limestone, and manganese ore, there is reason to believe that blast-furnaces might advantageously be started.

The Iron Ores of the Ural.—M. Verstraete † observes that the Ural district is extremely rich in iron ore. There are, to begin with, an enormous number of pocket deposits, some 500 small mines being at work in them, and in addition there are deposits of very large size, and even mountains of ore, capable of sufficing for centuries for the blast-furnaces of this and of adjoining districts. These ore deposits are not, however, spread equally over the whole of the Ural district. A part of the northern district is relatively poor in ore. This is the

* *Jahrbuch für Mineralogie*, 1890, p. 2.

† *L'Oural*, Paris, 1899.

part which comprises the provinces of Viatka and Vologda. There the iron ore mines are numerous enough, but they either contain small quantities of ore or the ore is of low grade. No deposit of any particular importance occurs in this district. The percentage of iron in the ores mined varies between 30 and 40, and the ore requires to be calcined. The ore is, however, very easily reduced. As the chain of mountains is approached the country becomes much more mineralised, and at the foot of the very highest summits of the Ural range are found the most famous of the iron ore mines. A number of mines here are mentioned by the author which belong to a company established with French capital, one of which, at Nijni-Chouvalsk, possesses a seam of about sixteen yards in thickness and containing from 50 to 60 per cent. of iron. These mines belong to the Volga-Vichera Company.

The author then proceeds to describe the Koutin mine. The ore found here is micaceous iron ore, containing 65 per cent. of iron. Unfortunately the deposit is nearly exhausted, it being now thought that only some 24,000 tons remain that can be extracted. This mine has been worked since 1893, the ore being sent to two adjacent blast-furnaces belonging to the Volga-Vichera Company. A number of other mines are also described. That of Joubrichkine contains ore in considerable quantity, but high in titanium and showing pyrites. The ore is stated to contain about 35 to 40 per cent. of iron. The quantity in sight is estimated at at least 250,000,000 poods. Before this deposit could be opened up it would be necessary to construct a railway to the Vichera.

The Chouvalsk mines are two in number. One of these is stated to contain ore which is described as a mixture of red hæmatite with magnetite, but only contains from 38 to 40 per cent. of iron. About 800,000 tons of ore are believed to be in sight. The other mine is, like the former, situated near the Vichera and contains large quantities of ore. One bed that has been met with is about sixteen yards in thickness and consists of ore containing about 60 per cent. of iron.

The Chondia mine contains brown hæmatites with from 40 to 60 per cent. of iron.

The Alexandrovski and Auerbach mines, belonging to the Bogoslovski Company, are on the other or Asiatic side of the mountains, about forty-three miles as the crow flies from Koutin. Red hæmatite is found here, containing about 65 per cent. of iron. More than 100 millions of poods of ore are estimated as being present in this mine. At the Auerbach mine there are two principal deposits, one of red

hæmatite with some 60 per cent. of iron, and the other of brown hæmatite of a lower percentage. These mines have been worked since 1893.

The most important mines of the Central Ural district are the Blagodot and Vissokaïa Gora. The former is situate near the Kouchva station on the railway from Perm to Ekaterinburg. This mine belongs to the State, and has been worked for over a century. The ore now in sight is about 13,000,000 tons. It is a magnetite with about 65 per cent. of iron. Its only fault lies in its gangue, which renders its reduction difficult. It is smelted in admixture with more fusible brown hæmatites, many deposits of which exist in the neighbourhood. Open-cast systems of working are employed. Only four million poods of ore are mined annually, and this is sent to ironworks belonging to the State.

The Vissokaïa Gora or High Mountain mine was worked in the reign of Peter the Great, rich magnetite being found. It has sent more than 3,500,000 tons of ore to the works of the Nijni-Taghil district, and large quantities are known to exist still in the property. The ore is magnetite, with about 66 per cent. of iron. It usually contains only very little copper, except in one part. The cost of extraction is three or four copecks the pood. Open-cast working is adopted. About twelve million poods are mined annually, five million poods being sent to the Nijni-Taghil works.

The total consumption of iron ore in the Central Ural district is about twenty-six millions of poods, and it will be seen that the two last-mentioned mines supply more than half. The other mines of this district are of secondary importance.

In the Southern Ural district the iron ore deposits are both rich and abundant. Many see in them the future safety of the works of the Donetz basin as regards their ore supply when the mines of the Krivoi Rog have come to an end. Its mineral resources are so vast that they are still quite unknown, fresh researches showing further deposits. The mines of the "Magnetic Mountain" and of Bakal are the most remarkable in this region. The former is situate on the Khirgiz Steppe, and represents probably a larger deposit of ore than any other as yet known to exist. At a depth of many dozens of fathoms ore is found in apparently unlimited quantity which contains from 64 to 65 per cent. of iron, and it can be so easily worked that the cost of mining can be maintained at two copecks the pood. This mine yields at present about 50,000 tons of ore a year.

The Bakal mine is situate at about forty-three miles from the town of Zlatoust. Its ores are well known, not only on account of their high percentage, but on account of their ready reducibility. They yield an excellent pig iron, which is stated to be as good as the best Swedish and very suitable for steel manufacture. Some seven million tons of ore are in sight at the present time.

In the province of Oremburg there are also a number of mines with ore containing about 50 per cent. of iron. The following are some analyses of ore from different parts of the Ural:—

District.	P.	Cu.	Mn.	Fe.	
Viatka	0·06	0·09	...	3·56	32·57
North	0·11	0·05	...	0·20	45·52
North	0·08	0·07	0·05	0·30	50·60
Central	0·03	0·11	0·03	0·06	66
Central	0·10	0·03	...	0·08	62
South	0·01	traces	...	2·60	60

Almost all the ores of the Ural are calcined at the mines, but at a few places, as at Vizel, they are calcined at the ironworks, at the latter place waste gases from the blast-furnaces being employed. Some interesting details are given as to mining costs and the Russian law relating to prospecting for and working new deposits of iron ore.

Iron Ore in Kursk Government, Russia.—Very marked magnetic declinations have been observed in the Kursk Government, Russia. A bore-hole was put down to a depth of 116 fathoms, but no ore was met with. A second bore-hole put down to a depth of 100 fathoms was equally unsuccessful. Alluvial deposits, sand, clay, sandstone, and limestone were passed through.*

Iron Ore of the Kertch Peninsula.—The brown iron ores worked at the mines of the Kertch Peninsula contain, on an average, 38 to 40 per cent. of iron, 2 to 4 per cent. of manganese, 17 per cent. of silica, 1 per cent. of phosphorus, and not more than 0·05 per cent. of sulphur. The deposits are of great importance as a source of supply for the South Russian blast-furnaces.†

The iron ore deposits of the Kertch and Taman peninsulas

* *Rigaer Industrie Zeitung*, vol. xxv. p. 272; *Chemiker Zeitung*, vol. xxiv.; *Reperitorium*, p. 36.

† Communicated by Mr. Sergius Kern.

are described by Bayard,* who gives a geological map of the peninsulas.

Ilmenite from Russia.—F. Kovár† states that the sand of a small lake in the granite district at Stephanowka, near Voronovica, Podolia, contains about a quarter per cent. of a black, granular mineral with metallic lustre and conchoidal fracture. Only a few grains are attracted by the magnet.

Analysis gave the following results :—

TiO ₂ .	FeO.	Fe ₂ O ₃ .	SiO ₂ .	Al ₂ O ₃ .	CaO.	MgO.	Total.
50·85	42·55	2·23	3·67	0·12	0·18	trace	99·60
51·20	43·04	2·06	2·98	0·20	0·14	trace	99·62

Iron Ore in Finland.—A magnetic survey by A. F. Tigerstedt ‡ has indicated the existence of enormous submarine deposits of magnetic iron ore, striking east and west in that portion of the Gulf of Finland in which the island of Jussarö is situated. The largest of the deposits is 2½ miles long, 100 feet wide, and of great depth. The iron ore deposits on the island itself are of less importance. A company has been formed to ascertain by boring whether it is possible to mine the submarine deposits.

Iron Ore in Spain.—J. A. Jones§ describes the Devonian iron ores of the Asturias, Spain, which range from 38 to 50 per cent. of iron, and form from 50 to 65 per cent. of the ore used at the works of Mieres, Felguera, Moreda, and Gijon. All the ores except at Bayo are found in regular beds conformable with the surrounding strata, and may be considered as sand beaches impregnated with iron oxide and formed in shallow salt water lakes. The various occurrences of ores are grouped under Cancienes and Molleda, Candás, Naveces, Llumeres, Carreño, and Bayo, and a short account and some analysis of each are given.

The discovery of iron ore deposits in the Sierra Cabrera, Almería, is announced. A deposit 20 yards in thickness has been found. ||

Iron Ore in Switzerland.—In Switzerland there is in the Bernese Oberland a bed of hæmatite that was well known in former centuries.

* *Annales des Mines*, vol. xv. pp. 505-522.

† *Zeitschrift für Kristallographie*, vol. xxxi. p. 525.

‡ *Fennia, Bulletin de la Société de Géographie de Finlande*, vol. xiv. pp. 1-19.

§ *Transactions of the Institution of Mining Engineers*, vol. xviii. pp. 279-292, with maps.

|| *Mining Journal*, vol. lxix. p. 1481.

The bed, which is several miles in length, has a thickness of 2 to 5 yards. Professor Heim estimates it to contain some 15,000,000 tons of ore. The ore is situated at an altitude of 6000 feet, and can be easily brought down by aerial ropeway to the proposed railway station at Innerkirchen. It contains 60 per cent. of iron, and it is proposed to smelt it by electricity, for which purpose ample water power is available.*

Iron Ore in Canada.—The Annual Report of the Geological Survey of Canada for 1897 contains a number of scattered references to the iron ores of the country. L. W. Bailey † shortly describes the iron ore of New Brunswick, and gives fuller details of the manganese ore deposits. Bog manganese ores seem to be widely distributed, and an average analysis of ore deposit, 25 to 30 feet thick at least, shows:—

Mn.	Fe.	S.	P.	Si.
45·81	9·95	0·03	0·05	5·36

E. D. Ingall ‡ gives a statistical account of the production of iron ore and iron, and of the imports of the several provinces. He also gives a tabulated series of 152 analyses of ores from Nova Scotia, with particulars of origin.

F. Pope § describes the occurrence in East Ontario of deposits of magnetite containing titanium and vanadium. The ores contain 6·41 to 17·23 per cent. of titanium oxide, and 0·23 to 0·63 per cent. of vanadium oxide.

A. Halsey || states that the iron ore mined on Taxada Island, British Columbia, has the composition:—

FeO.	Fe ₂ O ₃ .	Mn ₂ O ₃ .	TiO ₂ .	P ₂ O ₅ .	SO ₂ .	SiO ₂ .
28·33	67·31	trace	0·11	0·07	0·09	3·97

The ore in sight is estimated at from 5 to 11 million tons.

Canadian iron resources and possibilities are discussed by W. R. Nursey, ¶ especially in respect of the deposits and supply of ore.

New Zealand Ironsand.—A Parliamentary paper has just been published in New Zealand containing the correspondence which has

* *Revue Universelle des Mines*, vol. l. p. 110.

† Pp. 13M-19M; 43M-59M. ‡ Pp. 79S-118S.

§ *Berg- und Hüttenmännische Zeitung*, vol. lviii. pp. 556-557.

|| *Stahl und Eisen*, vol. xix. p. 1185.

¶ *Iron and Coal Trades Review*, vol. lx. pp. 783-784.

passed between the Colonial Government and an English syndicate on some trials made with New Zealand ironsand. On the whole, they have been successful in making high-class tool-steel in crucibles. By their process they find no difficulty in eliminating the titaniferous acid and other impurities. The process of conversion takes about three hours, and nearly all the metal in the sand is utilised. The sand has also been agglomerated without any added foreign matter. The iron produced was found on analysis to contain silicon, 0·07; sulphur, 0·01; phosphorus, 0·03; manganese, 0·33. There was no trace of titanium.

Iron Ore at Lake Superior.—The Association of Lake Superior iron ore selling firms has issued its usual list of cargo analyses of ore shipped in 1899, and in some cases those exported for 1900. The data are given for each of the five ranges, and include over 130 mines. They show the iron, silicon, phosphorus, manganese, alumina, lime, magnesia, sulphur, loss on ignition, and moisture.*

D. E. Woodbridge † gives a short general account of the progress and prospects of the Lake Superior district.

The Geological and Natural History Survey of Minnesota has issued an exhaustive report on the geology of the State, written by N. H. Winchell, assisted by U. S. Grant, J. E. Todd, W. Upham, and H. V. Winchell. The volume, which contains a detailed description of the iron ore mining industry of the district, is illustrated by thirty-one geologically coloured plates, forty-eight engravings, and 114 woodcuts. It is a valuable contribution to the knowledge of the great iron ore resources of the Lake Superior region.

Iron Ore in Georgia.—C. W. Hayes ‡ describes the geological relations of the iron ores in the Cartersville district of Georgia, which is one of the most productive iron ore districts of the Appalachians. Of the five distinct groups in the range, the district in question contains two, the specular hæmatite and the brown hæmatite or limonite, the latter being the more important, forming concentration deposits and fault deposits, though gossan ores and tertiary gravel ores are found in the vicinity. The limonites of the concentration deposits

* *Iron Trades Review*, March 1, 1900, pp. 20-21.

† *Mines and Minerals*, vol. xx. pp. 206-207.

‡ *Transactions of the American Institute of Mining Engineers, Washington Meeting, February 1900.*

occur wherever a limestone is underlain by an insoluble and impervious stratum, such as sandstone and quartzite, especially between the Beaver limestone and Weisner quartzite. Other ore deposits of the district include the ochre in the Cambrian quartzite, sometimes of considerable size. Manganese ores also occur in this district. Much ore has been mined, but in a primitive and inefficient manner.

S. W. McCallie* gives some notes on the brown iron ores in the north-western part of Georgia. They occur in the Lower Silurian, and to some extent in the Carboniferous and Cambrian formations. The most abundant are found in the Knox dolomite series of the first-named age, and some of the deposits are of considerable size in the form of pockets and irregular masses. Most are worked open-cast, and in a few cases the steam-shovel is adopted. A few log-washers are employed, but it is more usual to screen the ore and thereby lose the small stuff. Analyses show:—

Fe.	Mn.	Si.	P.
48.45—51.10	0.2—5.6	2.4—7.87	0.147—0.853

Brief accounts of the leading deposits are given.

Iron Ore in Ohio.—S. S. Knight† reviews the iron industry of Jackson County, Ohio, and briefly gives its history. From time to time twenty-three furnaces have been built in the district, but of the five now working only two are modern. Charcoal was largely used, but has mainly given way to the local coal, of which there are several seams of non-caking coal. A section is given to show the relative position of the various coal seams, iron ores, and limestones in the district. Of the latter several analyses are given, the ores most usually worked containing:—

SiO ₂ .	Fe.	P.	S.	Mn.	Al ₂ O ₃ .	CaO.
38.00	34.55	0.14	trace	0.81	4.80	2.50
11.20	48.24	0.25	0.106	1.00	5.25	0.67

The ores are of all kinds, brown ores, hæmatite and spathic ore.

Iron Ore in China.—A report to the Pekin Syndicate by J. G. H. Glass‡ deals with the proposed railways and with the coal and iron

* *Engineering and Mining Journal*, vol. lxix. pp. 255-256.

† *Iron Age*, December 7, 1899, pp. 11-13.

‡ November 1899.

deposits in the provinces of Shansi and Honan in China. Two analyses of iron ore from Tai Yang show :—

Silica.	Iron.	Alumina.	Manganese Oxide	Lime.	Phosphorus.	Sulphur.
4·67	53·88	3·46	0·570	2·21	0·250	0·074
11·15	45·50	6·42	0·512	5·50	0·469	0·016

Iron ore is widely distributed, mainly as limonite and hæmatite. Included in the report are notes by W. H. Shockley on these deposits, and on the native methods of manufacturing iron and of obtaining the ore and fuel. The observations of Baron von Richthofen are referred to in the highest terms.

Some amendments made in July 1899 to the regulations for mining in China have been published ; * and A. Dieseldorff † has given a detailed description of the iron ore deposits of Schantung.

Iron Ore in Japan.—According to O. Vogel, ‡ Japan is rich in magnetic iron ore and red hæmatite, and in magnetic iron sand. The known beds of iron ore are estimated to contain 70,000,000 tons. For smelting the ore small furnaces three feet in height, and serving for only one charge, were used. The first blast-furnace was built in Kamaischi in 1860, by a Japanese from Dutch drawings. In 1875 David Forbes, Foreign Secretary of the Iron and Steel Institute, built two small charcoal blast-furnaces at Heigori, as well as twelve puddling furnaces and a forge and rolling-mill. Recently the Japanese Government has voted £900,000 for the erection of a modern iron and steel works. The plant comprises two blast-furnaces, 200 coke-ovens, two Bessemer converters, and four open-hearth furnaces. The output will be 90,000 tons of finished iron and steel.

Iron Ore in Persia.—H. Winklehner § states that iron ores occur in many parts of Persia, but in no place is the deposit of any great importance. Some of the occurrences are enumerated by the author. One deposit mentioned is of somewhat greater importance, however, as far as actual quantity is concerned. It lies near Bam, far out in the desert, and consists of a seam of red hæmatite ten to twenty yards in thickness. This occurs in limestone, and can be traced for between 800 and 900 yards. The ore is of excellent quality, and contains on

* *Engineering and Mining Journal*, vol. lxviii. pp. 549-550.

† *Zeitschrift für praktische Geologie*, 1899, pp. 206-209.

‡ *Mining Journal*, vol. lxx. p. 32.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 645.

the average 56 per cent. of iron. The position of the deposit is, however, such as to render it commercially valueless. Scarcely any water occurs in the neighbourhood.

Iron Ore in Togo.—According to F. Hupfeld,* iron ore occurs in considerable quantities in the crystalline schists of the German colony of Togo, and is smelted by the natives at two localities—in the Basari-Banyeri district, and at Boëm, in the western portion of the central Togo Mountains. The ore smelted at Banyeri contains 68·9 per cent. of iron, and 0·017 per cent. of phosphorus, whilst that at Boëm contains only 54·88 per cent. of iron and 0·41 per cent. of phosphorus.

Iron Ore in San Domingo.—In the island of San Domingo, near Cotui, fifty miles from Samana Bay, extensive deposits of valuable iron ore have been discovered. The ground belongs to the Government, and the mines are twelve miles from a navigable river flowing into Samana Bay.†

Recent Researches on Meteorites.—Prince Krapotkin ‡ states that the number of small meteorites which annually reach the earth is estimated at 146,000,000, but they are so small that it would take 100,000 years for their dust to raise the surface of the globe by a single inch.

Emil W. Cohen § publishes a review of the literature concerning the structure of various meteoric irons. Describing the meteorite from Shingle Springs, El Dorado County, California, it is noted that in the large proportion of nickel and in the bright etching spots, this resembles the Cape of Good Hope, Iquique, and Kokomo irons. Analysis gave results corresponding with the following mineralogical composition: Nickel iron, 97·65; nickel iron phosphides, 2·21; troilite, 0·14. In the case of the meteorite from Magura, Hungary, the angular fragments left after dissolving the iron in very dilute hydrochloric acid gave, on analysis, results showing that, as in other irons, this material consists mainly of kamacite, with perhaps a little tænite.

Previous analyses of tænite (a nickel iron) show the presence of small amounts of carbon. New determinations made on tænite from

* *Mining Journal*, vol. lxx. p. 501.

† *Industrielle Nachrichten*, May 5, 1900.

‡ *Nineteenth Century*, December 1899.

§ *Annalen des k.k. naturhistorischen Hofmuseums*, vol. xiii. pp. 473-486.

Toluca and Glorietta Mountain irons gave 0·22 and 0·12 per cent. of carbon respectively.

O. Sjöström* gives the details of the methods of separation and estimation used by him in the analysis of meteoric irons. The methods are essentially the same as those outlined by Cohen, and several of the author's analyses are given in recent papers by Cohen.

Carl Hödlmoser† gives the following as the bulk analysis of the stone which fell at Zavid, in Bosnia.

SiO ₂ .	Al ₂ O ₃ .	Fe.	FeO.	CaO.	MgO.	Na ₂ O.	K ₂ O.	H ₂ O.	S.	Total Less O for S.
41·90	1·92	0·15	27·40	4·60	22·79	1·05	0·41	0·39	1·01	101·11

Also traces of cobalt, nickel, and manganese. The metallic iron was estimated from the amount of hydrogen liberated when the material was treated with acid.

According to P. G. Melikoff,‡ analysis of the meteorite which fell at Zmjenzj, Minsk, in West Russia, in August 1858, gave I. for the portion soluble in hydrochloric acid, and II. for the insoluble portion; in I. also FeS, 1·32; Fe₂Ni, 0·32; P₂O₃, 0·08.

	MgO.	CaO.	FeO.	MnO.	Al ₂ O ₃ .	K ₂ O.	Na ₂ O.	Fe Cr ₂ O ₄ .	Total.
I.	9·72	1·20	3·98	1·03	0·41	6·27	0·13	0·56	25·02
II.	38·46	15·61	1·86	13·45	1·76	1·79	0·25	1·19	74·93

The mineralogical composition is: Anorthite, 23·3; bronzite, 74·36; troilite, 1·32; chromite, 0·56; nickel iron, 0·32 per cent. In the ground-mass of anorthite and bronzite are porphyritic crystals of yellow bronzite with the composition 2MgSiO₃, FeSiO₃. The crust of the meteorite contains magnetite, which has originated by the fusion of the bronzite.

The meteorites from Jamyscheff and Tubil River, Siberia, are described by J. A. Antipoff.§ Analysis I. is one of the metallic portion of the meteorite which fell in the neighbourhood of the village of Jamyscheff, Pawlodarsk district, in Semipalatinsk (it contains also graphite, 0·115; howardite, 0·595; magnetite, 2·284). The olivine gave the results under II., agreeing with the formula

* *Mittheilungen des naturwissenschaftlichen Vereines für Neu-Vorpommern und Rügen*, vol. xxx. pp. 1-29.

† *Tschermaks Mineralogische Mittheilungen*, vol. xviii. pp. 513-517.

‡ *Journal of the Chemical Society*, vol. lxxvi. p. 771, from *Journal of the Russian Chemical Society*, vol. xxviii. pp. 114, 299, 307.

§ *Bulletin de l'Académie Impériale des Sciences, St. Petersburg*, vol. ix. pp 91-103; *Journal of the Chemical Society*, vol. lxxviii. p. 220.

(Mg, Fe₂) SiO₃. Analysis III. is of the meteoric iron found on the Tubil River, Atshinsk district, government of Yeniseisk.

	Fe.	Ni.	Co.	SiO ₂ .	Ca.	Mn.	Mg.	As.
I.	86.634	7.985	0.603	0.160	0.392	...	0.057	trace
III.	95.183	3.385	0.140	0.075	0.205	0.090	0.033	0.019

	Cl.	C.	O.	S.	CO ₂ .	H ₂ O.	Schreibersite.	Total.
I.	0.120	0.071	0.509	0.012	0.047	0.144	0.366	100.094
III.	0.038	0.120	0.093	...	...	...	0.425	99.806

	SiO ₂ .	FeO.	Al ₂ O ₃ .	MgO.	MnO.	SnO ₂ .	Total.
II.	39.80	16.34	0.27	43.68	trace	trace	100.11

Warren M. Foote,* states that the meteoric iron, originally weighing about 3 lbs., was found in 1898 near Iredell, Bosque County, Texas. It differs from other Texas irons in the fine pitting and the absence of Widmanstätten figures on an etched surface. Analysis of material partially freed from schreibersite gave the following results:—

Fe.	Ni.	Co.	P.	S.	Total.
93.75	5.51	0.52	0.20	0.06	100.04

H. L. Preston† describes the Illinois Gulch meteorite found in Montana in 1899 four feet below the surface. It weighs about 2435 grammes, shows no distinct structure on etching, contains but little troilite, and on analysis shows:—

Fe.	Ni.	Co.	Si.	P.	C.
92.51	6.70	0.16	trace	0.62	0.01

The Ward-Coonley collection of meteorites is described by H. A. Ward.‡ It includes 424 occurrences, with an average weight of 7½ lbs. Each specimen is described, and the work contains a number of etched plates.

It is stated§ that the great 100-ton meteorite brought from Greenland by Lieutenant Peary is still lying unsold in the Brooklyn Navy Yard. The price is given as 75,000 dollars.

Manganese Ore in Colorado.—There is now mined in Colorado about 10,000 tons of manganese ore per month.|| The percentage of manganese averages about 25, but it varies between 17 and 35. The ore is usually sold on a basis of three dollars per ton of ore containing 28 per cent. of manganese and 24 of iron, 8 cents being taken off for

* *American Journal of Science*, vol. viii. pp. 415–416.

† *Ibid.*, vol. ix. pp. 201–202.

‡ "The Ward-Coonley Collection of Meteorites," p. 100, plate vi., Chicago, 1900.

§ *Globe*, April 27, 1900. || *Stahl und Eisen*, vol. xix. p. 1135.

1900.—i.

every 1 per cent. of manganese below 28, and 10 cents added for every 1 per cent. of manganese above that figure.

Manganese Ore in Brazil.—The manganese deposits of Bahia and Minas, Brazil, are described by J. C. Branner.* The Pedras Pretras Mine, from which the chief amount is produced, is 16 miles west of Nazareth. The ore is psilomelane, and occurs in decomposed crystalline schists. It is cleaned by drying it over a fire, and then chipping off the dry clay with hammers. The Minas Geraes deposits are near the Ouro Preto branch of the Central Railway, about 280 miles from Rio, and at Queluz, on the main line. Several analyses of the ore from different localities are given, with the following analysis, showing the average of 40,000 tons of ore sent to New York:—

Mn.	P.	Si.	Fe.	H ₂ O.
54.08	0.03	1.05	0.90	7.60

Two manganese mines † are being opened up in the State of Bahia, Brazil, about 16 miles from the town of Nazareth, on the Jaguaripe river. The ore is psilomelane, averaging 42 per cent. of manganese oxide.

II.—IRON ORE MINING.

Exploring for Iron Ore.—P. Ulrich ‡ describes the Swedish methods of exploring for magnetic iron ore with the aid of the magnetometer. The methods referred to have been previously described in this Journal by Bennett H. Brough § and by G. Nordenström.||

R. Thalen ¶ describes recent improvements in instruments used in the exploration for magnetic iron ores.

Deep Boring.—A. C. Lane ** gives some interesting details of the speed of drilling deep holes. In the Lake Superior district the num-

* *Transactions of the American Institute of Mining Engineers*, California Meeting, September 1899.

† *Iron and Coal Trades Review*, vol. lix. p. 762.

‡ *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1899, pp. 1-42, with three plates.

§ *Journal of the Iron and Steel Institute*, 1887, No. I. pp. 289-303.

|| *Ibid.*, 1898, No. II. pp. 35-75.

¶ *Jernkontorets Annaler*, 1899, No. 6.

** *Engineering and Mining Journal*, vol. lxxviii. p. 548.

ber of hours required for drilling the first and each successive hundred feet, an average of fourteen holes, is as follows:—I. 89·1, II. 85·3, III. 87·4, IV. 105·6, V. 114·3, VI. 138·1, VII. 123. For an aggregate of 8100 feet drilled in these fourteen holes, the average depth drilled per hour was 0·95 foot.

H. M. Lane* gives some notes on diamond drilling, and describes the methods of putting down the stand-pipes, making watertight joints between the rock and casing, drilling-guides, &c.; the recovery of lost rods, bits, and diamonds; the core barrel and core-holding devices, water supply, setting diamonds, &c. Some of the different types of machinery are then described and illustrated. He describes some of the peculiarities, advantages, and disadvantages of the different types of diamond drilling machines in use, and especially dwells upon the feed mechanism of which the hydraulic, positive gear, and friction feeds are described. The thrust bearings, and the method of uncovering the hole by moving the whole machine or the head only are also dealt with.†

Electric Percussion Drill.—Results are given that have been obtained with a Siemens and Halske electric percussion drill at Hallein, and also other results obtained with a similar drill at Dürnberg in hard limestone. The results in both cases were very satisfactory. In the former case, as compared with hand labour, it was 2·18 times as cheap and 528 per cent. more rapid.‡

Haulage in Iron Ore Mines.—A plan of the Aragon iron mine, Norway, Michigan, and an illustration of the compressed air locomotives used, has recently appeared.§ The air is compressed in a three-stage compressor, with air cylinders 10½, 7¾, and 2½ inches in diameter, and steam-cylinder 14 inches with a 16-inch stroke to a pressure of 800 lbs. A three-inch main carries the air to storage tanks under ground. The locomotive weighs 7 tons and measures 5½ by 4½ by 13 feet over all, and has four 24-inch wheels on a 4-foot base and a gauge of 22½ inches. It is charged with air in 30 to 60 seconds, and will haul twenty trucks, the loaded train and locomotive weighing 43 tons. A thousand tons are handled in ten hours.

* *Mines and Minerals*, vol. xx. pp. 101, 160, 193, 241.

† *Ibid.*, vol. xx. pp. 241-245.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 556-557.

§ *Iron Trades Review*, October 12, 1899, pp. 14-15.

Unwatering Mines.—W. Kelly * describes several methods adopted in the Lake Superior district for balancing the bailers used in winding water from the mines where independent winding-drums were employed. In the first plan used a counterbalance was used to aid in starting the loaded tank, and in the other plan a third rope connected the two tanks and passed over the separate winding-drums. By properly manipulating their brakes, the weight of the empty bailer assisted the other to rise.

Mine Dams.—J. Macnaughton † describes the construction of some dams at the Chapin Mine in Michigan to stop out the watercourses encountered in the limestone. In one case a cavity was found from which the water issued at a pressure of 276 lbs. It was siphoned to the pumps temporarily, while the passage was cleared of loose rock. A timber platform was put in and the place filled with concrete, consisting of one part of Portland cement, two of sharp sand, and four of broken limestone, to a depth of 17 feet. A 10-inch pipe was placed in position, and to take off the water and the joint between it and the concrete made with cement and sand after each foot of concrete was rammed. In another place water was encountered at a pressure of 355 lbs., and was finally stopped out by a horizontal concrete dam 22 feet long. During the construction a temporary dam was erected to hold up the water to a height of 5 feet, and the water led away by a launder; but after the main dam was carried to a suitable height, the water was allowed to run through an 8-inch pipe placed near the bottom. When the dam was within 9 inches of the top, it was completed with brickwork set in cement, as concrete could not be rammed in so small a space. To further strengthen the dam, 70-lb. rails were placed horizontally in the concrete and cemented into hitches 6 inches deep in the walls, and two vertical steel girders 13 feet long, 20 inches deep, with 12-inch flanges, were placed at the back to bear against the rails and concrete. They were cemented in hitches 13 inches deep. In four weeks' time the pipe was closed, and the dam successfully withstood the pressure, although it attained 440 lbs. per square inch.

Mine Signals.—A. W. Thompson ‡ describes the electric bell signals used in the winding-shaft at the West Vulcan Mine in Michigan,

* Paper read before the Lake Superior Mining Institute, February 1900; *Iron Trades Review*, March 22, 1900, p. 18.

† Paper read before the Lake Superior Mining Institute, February 1900; *Iron Trades Review*, March 15, 1900, pp. 18-19.

‡ Paper read before the Lake Superior Mining Institute, February 1900; *Engineering and Mining Journal*, vol. lxi. p. 378.

where the ice in winter prevented the operation of pull signals. Good insulation is requisite, and the means for obtaining it are described.

Mining in the Lake Superior District.—O. C. Davidson * describes the methods of mining at the Badger Mine at Commonwealth, Wisconsin. The ore body was about 500 feet in length, and from 20 to 90 feet in width, covered with 12 to 20 feet of drift. This was removed, and the ore won by open-cast working to a depth of 180 feet in parts, but underground mining was found to be more economical, as so much of the hanging wall had to be removed at this depth. The ore was then worked to a depth of 540 feet by levels 90 feet apart, and the pillars ultimately removed by a top-slicing system, of which some details are given.

W. Kelly † deals with the advances made in the Lake Superior district in mining iron ore, referring generally to the increase in the use of mechanical appliances and to the amount of work handled by them. Economy in labour and material is also shortly discussed in a general way.

The sixth annual meeting of the Lake Superior Mining Institute took place in February 1900, and accounts of the visits to various mines and of the papers read have been published.‡

Some photographic illustrations of the Mahoning iron ore mine on the Mesaba range have appeared.§ An area of 1800 by 300 to 400 feet, or about 30 acres, has been stripped of the surface soil to a depth ranging from a few feet up to 35 or 40 feet, over a million cubic yards of earth being removed, leaving the ore exposed for the steam-shovels. In the season of 1899 about 485,000 tons of ore with 63 per cent. of iron and 0·05 phosphorus, and 265,000 tons of ore with the same percentage of iron but 0·05 to 0·07 of phosphorus, have been raised. The ore is sampled *in situ* by pits sunk at intervals of 50 feet, and samples are taken from every 100 tons on the railway trucks. The ore is worked in terraces 23 feet in height by steam-shovels with dippers holding 5 tons each. Holes enlarged with dynamite and then charged with five or six kegs of black powder are used to loosen the ore, so that each of the three 65-ton shovels can raise about 3000 tons monthly.

* Paper read before the Lake Superior Mining Institute, February 1900; *Iron Trade Review*, February 22, pp. 19-20.

† Presidential address to the Lake Superior Mining Institute; *American Manufacturer*, vol. lxvi. pp. 211-212; *Iron Trade Review*, February 15, 1900, pp. 16-17.

‡ *Engineering and Mining Journal*, vol. lxi. p. 195.

§ *Iron Age*, November 9, 1899, pp. 1-3.

Handling Iron Ore.—An exhaustive monograph, covering 100 pages, on aerial wire ropeways has been written by E. Sobo, of the School of Mines, Schemnitz, in Hungary. This has been translated from the Hungarian into German by L. Litschauer.* The great advantages presented by this ingenious method of transport in the mining and metallurgical industries are clearly shown. The historical notes given are full of interest. Ropeways of primitive design have been used since the earliest times. The first ropeway based on technical principles appears to have been used in 1411. In 1644 the Dutch engineer, Adam Wybe, built a ropeway for transporting earth at Dantzig. Its capacity was, however, very small, and no progress was made until the year 1833, when the invention of the wire rope by Albert of Clausthal gave the first start to the development of wire rope transport. In 1871 Baron F. Ducker constructed a ropeway at Bochum with double wires. In 1877 Hodgson, in England, invented his ropeway, in which double wires were also used. There are now three main systems adopted :—1. Ropeways with fixed wire, on which the carriage runs down by its own weight ; 2. Wire ropeways of the English or Hodgson system, in which the load is carried on an endless rope ; and 3. The German or Ducker system, in which the bearing rope is fixed, and on it the carriage is drawn by an endless hauling rope. The last system has of late years been greatly improved by Bleichert, Otto, Obach, and Pohlig.

The iron mines of the Sierra Almagrera have been rendered easily accessible by the erection of an aerial wire ropeway of the Hodgson type, which has just been started.† Its length is 1606 metres. The loading station is 252 metres above sea-level and the discharging station 30 metres above sea-level. There are 29 columns, varying from 14 to 27 metres in height. The spans are usually 25 to 40 metres, but there are seven varying from 60 to 105 metres and two across streams of 204 and 206 metres respectively. The capacity of the line is 320 tons in twelve hours.

W. Hewitt ‡ gives a number of illustrations of wire ropeways and details of the plant employed.

W. Fawcett § gives an illustrated description of some of the means adopted in the Lake Superior district for loading iron ore into railway

* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xlviii. pp. 369–464.

† *Revista Minera*, vol. i. pp. 484–485.

‡ *Cassier's Magazine*, vol. xvii. pp. 502–512.

§ *Engineering and Mining Journal*, vol. lxix. pp. 77, 107.

trucks, and into the Lake vessels at the various docks, and also some illustrations of some of the larger vessels employed. Other figures show two types of bridge unloaders for transferring ore from the vessel to the railway and the furnace-charging apparatus at Duquesne is also illustrated.

Other illustrations of the Lake steamers have also appeared.*

Illustrations have appeared † of the Hulett machine for unloading ore from ships. A grab holding ten tons is mounted on a leg at the end of a pivoted beam which is carried by a traveller. The leg is kept in a vertical position when the beam is tilted by a parallel motion and hydraulic power is used for operating.

Further illustrations have appeared ‡ of the Hulett hydraulic machine for unloading ore from the vessels on the Great Lakes by means of a 10-ton bucket carried by an arm on the end of a walking beam.

III.—MECHANICAL PREPARATION.

Ore Concentration at the Pewabic Works.—L. M. Hardenburg§ describes the iron ore concentration process at the Pewabic works in the Lake Superior district. The ore is distributed fairly evenly through sandstone in pieces varying from the size of a pea up to masses of several hundred pounds weight, and it separates readily from the sandstone when crushed, so that no intermediate products are made in the treatment. The run of the mine is screened over bars with $1\frac{1}{2}$ -inch openings, and the coarse material is hand-picked on a travelling belt 13 feet long and 12 inches wide. Pure ore and rock are removed as far as possible by hand, and the remainder falls into a 14 by 20 Blake crusher, then passes over a screen with $\frac{3}{4}$ -inch spaced bars into rolls, and then into tromeels. The material passing through the first-mentioned screen is also crushed in rolls and screened in tromeels. The various sizes made are treated in jigs, the larger sizes in nine three-compartment jigs, while the material passing the $\frac{3}{16}$ -inch screen is distributed by hydraulic separators to nine two-compartment jigs, of which further particulars are given. The ore

* *Engineering and Mining Journal*, vol. lxix. p. 173.

† *Iron Trade Review*, November 9, 1899, pp. 12-13.

‡ *Engineer*, vol. lxxxix. pp. 330-331.

§ Paper read before the Lake Superior Mining Institute, February 1900; *Iron Trade Review*, March 8, 1900, p. 12.

and rock have specific gravities of 2·6 and 5·0, so they are readily separated. Automatic side discharges lead the ore to the storage hoppers. Both crude and clean ore are washed down launders, with a slope of $2\frac{1}{2}$ inches per foot, to the desired point, as it was found that conveyors wore out too quickly. The capacity of the mill is 280 to 300 tons of crude ore daily. Three men and eight boys are required per shift, and power is given by a 65-horse-power engine.

Magnetic Concentration.—E. Ferraris describes the magnetic concentrator that has been used since January 1898 at the Monteponi Mine in Sardinia. It consists essentially of a fixed horseshoe electro-magnet placed with its poles downwards. Below the poles is an endless rubber belt a foot wide, at a distance that may be varied at will. A hopper feeds on to the belt a thin layer of the material to be treated, which is carried forward by this belt at a velocity of $1\frac{1}{2}$ foot a second. In order to collect the portion attracted by the magnet, a second endless belt moves horizontally in a direction at right angles to the first, close to the poles of the magnet. The magnetic plant at Monteponi treats in twenty-four hours 24 tons of material previously submitted to a reducing roasting. The material consists of silicate of zinc more or less ferriferous, limonite, and zinciferous dolomite, materials of almost identical specific gravity. In the raw state the material contains on an average 22 per cent. of zinc, a percentage which is brought up to 30 by roasting. The magnetic concentrator extracts about a third of the iron ore, assaying 10 per cent. of zinc, whilst the remaining product is brought up to 40 per cent. of zinc. By treating this product in hydraulic jiggers the lime and magnesia from the dolomite are removed, and the final product—oxide of zinc—contains 48 per cent. of zinc.*

The electro-magnetic concentration of iron ore is discussed by De Neusville† with special reference to the Wetherill process.

* *Mining Journal*, vol. lxi. p. 1252.

† *Zeitschrift für angewandte Chemie*, 1900, pp. 52-53.

REFRACTORY MATERIALS.

Fireclay.—H. Seger* and E. Cramer give analyses of a newly opened-up bed of fireclay in the Upper Palatinate. In their preliminary remarks the authors observe that, as a rule, those fireclays are preferred in practice which have a high percentage of alumina, a high melting-point, and possess the capacity of burning dense at a relatively low temperature. In making a mixture for firebrick manufacture, the size, shape, surface, character, &c., of the pieces used is of the very greatest importance, as well as the ratio by weight that the fireclay bears to the clay used for binding. Not every plastic clay is suitable for this purpose, especially such as contract considerably. The products in this case are full of cracks and do not possess the necessary strength. To avoid this in practice another clay must be taken or powdered firebrick added. The clays mined by the Upper Palatinate Clay Company are, the authors state, extremely plastic and sinter at a relatively low temperature while possessing a very high melting-point. They are therefore similar to those of Gross-Almerode, Westerwald, and Hettenleidelheim. Analysis of the clay showed :—

	Per Cent.
Silica	44·70 to 45·65
Alumina	35·28 „ 36·51
Ferric oxide	1·94 2·48
Lime	trace 1·03
Magnesia	Nil 0·63
Loss on ignition	15·74 16·66
Alkali	not determined

The four analyses shown total from 99·78 to 100·13.

The burnt material would contain about 54 per cent. of silica, 42 of alumina, and 2·7 of ferric oxide. They are therefore relatively high in alumina. The melting-point lies between Nos. 33 and 34 of the

* *Stahl und Eisen*, vol. xix. pp. 1063-1064.

Seger scale. Heated to the melting-point of No. 1 of the scale, the clay is burnt almost to its greatest density. Samples burnt at this temperature subsequently absorbed from 0·6 to 1·1 per cent. of moisture.

H. Foster * gives the following analysis by C. Wood of a fireclay found at Lal Lal in Victoria :—

Insoluble silicate of alumina	92·60
Soluble	1·33
Oxide of iron	trace
Soluble silica	0·53
Water driven off at a red heat	5·80
Total	100·26

E. Envall † describes the manufacture of fireclay crucibles in Germany and Austria.

The occurrence and mining and mechanical preparation of the refractory shale in the Neurode district are described by Bobisch. ‡

Firebrick.—At a firebrick plant at Mount Union, Pennsylvania, the ganister is brought by an inclined self-acting plane 1750 feet in length to a crusher, which delivers the material to four grinding pans, each with a capacity for 4000 bricks in eight hours. The drying floor, 200 by 140 feet, is heated by exhaust steam and there are twelve kilns.§

Magnesite.—S. J. Vlasto || gives two photographs of the Grecian magnesite workings. The deposits referred to exist in the island of Eubœa on the east coast, and also near Corinth. They occur in small bare hills, and are worked open-cast. The production in Greece during 1899 is estimated at 30,000 to 35,000 tons, of which 20,000 tons went to America. It contains nearly 97 per cent. of carbonate of magnesium with traces of iron, and not more than 0·04 per cent. of silica. The magnesite is also calcined and made into bricks in the country, about a thousand persons being employed in the industry. Some reference is also made to the deposits of other countries.

It is stated ¶ that the manufacture of magnesite firebricks has been

* Geological Survey of Victoria, Monthly Progress Report, 1899, p. 7.

† *Teknisk Tidskrift*, vol. xxx. pp. 38–42.

‡ *Bergbau*, 1900, No. 19.

§ *Iron Trade Review*, March 8, 1900, p. 15.

|| *Engineering and Mining Journal*, vol. lxix. pp. 288–290.

¶ *Ibid.*, vol. lxxviii. p. 484.

started at two places in Pennsylvania. Most of the material is imported, but some is obtained at Layton.

Graphite.—E. Weinschenk * describes the Styrian graphite deposits. Workable seams of graphite occur in the States between the Ober-Ennsthal and the Semmering. The seams appear to have been formed by the action of granite intrusions on coal deposits of Carboniferous age.

R. H. Palmer † gives an account of some graphite workings at Cranston, Rhode Island. The vein is about 12 to 15 feet in thickness, and is worked from several levels.

C. F. Wheelock, jun., ‡ describes the mining of graphite in Alabama. Two establishments are at work in Cleburne County. The operations of dressing the ore are described.

F. Kovar § states that the graphite from Klein-Tressny, Moravia, contains 39·60 to 42·35 per cent. of carbon, the remainder consisting of ash with 1·5 per cent. of water.

* *Zeitschrift für praktische Geologie*, 1900, pp. 36–44.

† *Engineering and Mining Journal*, vol. lxviii, p. 694.

‡ Paper read before the Alabama Industrial and Scientific Society.

§ *Jahrbuch für Mineralogie*, 1900 p. 25.

FUEL.

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I.—CALORIFIC VALUE.

Calorimetry.—An oxygen calorimeter for testing fuel oil and combustibles has been recently devised by J. R. Chapman. The material is burnt in a chamber enclosed in a large water vessel.*

W. Kent † expresses the opinion that the Carpenter calorimeter is not so accurate an instrument as the Mahler calorimeter. The results of the tests tend to show that the coals mined in a given seam over a considerable area of territory have a substantially uniform heating value per pound of combustible matter.

Pyrometry.—The measurement of very high temperatures is always a matter of great interest, whether viewed from the purely physical standpoint or from the technical side. The early experiments of Wedgwood, dating back more than a hundred years, form a starting-point in the development of the subject, while the recent experiments of Le Chatelier, Barus, Holborn, and Wein, and others show how much may be accomplished in this direction. H. Le Chatelier and O. Boudenard have now published ‡ a very useful and compact *résumé* of the

* *Iron and Coal Trades Review*, vol. lx. p. 122.

† *Transactions of the American Society of Civil Engineers*, vol. xlii. pp. 86-91.

‡ *Mesure des Températures Elevées*, pp. 220, 8vo, Paris, 1900.

entire subject, taking up the various forms of pyrometers in succession, according to the physical principles involved in each. The whole forms a most interesting discussion, and brings out clearly the point which science has now reached, as well as the limitations of the present methods. The author notes that in order to reach a higher degree of precision than has yet been attained a more exact determination of the fixed points serving for the graduation of the pyrometer is much to be desired, since, for example, the points of fusion of zinc, silver, and gold are still uncertain to some 10 degrees. Furthermore, a more precise determination of the relation between the electrical resistance of platinum and the temperature is needed; while for the very highest temperatures it would be useful to have a more definite knowledge of the laws of radiation of an absolutely black body.

Illustrations are given * of Steinle's steel mercury thermometer for temperatures up to 950° F. The mercury is contained in a very fine bore in a wire connected with a flattened coiled tube, which its expansion causes to uncoil, the amount being shown on a dial.

A. Hill † gives some notes on the measurement of high temperatures by the thermo-electric couple used with a special form of the D'Arsonval galvanometer calibrated by sending definite and increasing currents through it from an external source. The use of pyrometers in works is discussed.

E. A. Uehling ‡ again describes his pneumatic pyrometer and autographic recorder, giving particulars of its construction and use. The appliance is in use at more than 150 places both for determining temperature and composition of gases.

Calorific Value of Lignite Briquettes.—Isaac § discusses the use of lignite briquettes, and deals with their calorific value.

II.—COAL.

Coal in South Wales.—A memoir on the geology of Newport, Monmouthshire, by Aubrey Strahan, has been issued by the Geological Survey. It is notified as the first part of a general memoir on the

* *Engineering*, vol. lxi. p. 415.

† *Journal of the West of Scotland Iron and Steel Institute*, vol. vii. pp. 51-72.

‡ Paper read before the Cleveland Institution of Engineers, January 22, 1900; *Proceedings*, pp. 61-94.

§ *Bulletin de l'Association Belge des Chimistes*; *Colliery Guardian*, vol. lxi. p. 499.

geology of the South Wales coalfield. The original geological survey of that large area was commenced more than sixty years ago by De la Beche, and it is but natural that the old one-inch maps have long been out of date. The re-survey was commenced in 1891, and now a large part of the coalfield has been mapped in detail on the six-inch scale. These larger maps are deposited for reference in the Geological Survey Office in Jernyn Street, while the one-inch maps which are published afford a good general idea of the structure of the country. Of these, sheet No. 249 is now described. The main advances made are in the subdivision of the Old Red Sandstone and of the Coal Measures, and in the tracing out of the faults and disturbances which have affected the position of the productive coal strata. The memoir contains the results of a systematic survey, whereby the variations in the character and thickness of the strata have been followed, and the numerous coal seams have been tabulated and correlated. The practical importance of the work in the colliery districts will be appreciated by those interested in the further development of the great coalfield. On scientific grounds geologists will find matter of interest relating to the Silurian rocks and fossils of the Usk district, as well as in regard to the Old Red Sandstone, Carboniferous rocks, Keuper marls, Rhætic beds, and Lower Lias. It is noteworthy that there appears to be a sharp plane of demarcation between the Silurian and Old Red Sandstone, and that no break has locally been found in the series of strata which constitute the Old Red Sandstone.

Coal in Staffordshire.—W. Gibson * discusses the existence of Coal Measures to the west of the Staffordshire anticline.

Coal in Durham.—A list of the collieries that produce coking coal in Durham, with the number of hands employed by each, both above and below ground, with a map showing their distribution, has been published.†

Coal in Scotland.—R. W. Dron ‡ discusses the probable duration of the Scottish coalfields, and shows that from 1854 to the present date the output of coal from Scotland has represented on an average

* Paper read before the North Staffordshire Field Club; *Colliery Guardian*, vol. lxxix. p. 211.

† *Iron and Coal Trades Review*, vol. lx. pp. 74-75.

‡ *Transactions of the Institution of Mining Engineers*, vol. xviii. pp. 104-212.

13·3 per cent. of the output of the United Kingdom. On the assumption that the Scottish output had always maintained the same ratio to the output of the United Kingdom, it is estimated that the total amount of coal worked in Scotland to the present time is 1,504,000,000 tons, and 10,121,000,000 tons of coal are still available. All the proven coal in Scotland would be exhausted by the year 1989, and the reserve coal by 2080. The output of Lanarkshire and Stirlingshire was nearly double what it was in 1878, whereas the output of Ayrshire in 1898 was only 500,000 tons more than it was in 1878. The output of Fifeshire, on the other hand, was now almost three times as great as it was in 1878—a remarkable contrast to the stagnation of the Lothians and Ayrshire.

Correlation of British and Continental Coalfields.—Dr. Wheelton Hind * gives the results of his observations on the correlation of the British and European Carboniferous beds, especially below the Millstone grit, to which he has devoted so much attention in the Midland district of England. The palæontological element is strongly developed.

M. Stirrup † discusses the value of fossil plants of the Coal Measures as stratigraphical guides.

J. Lomax ‡ describes some recent investigations of the plants of the Coal Measures.

Coal in Austria.—C. F. Eichleiter § has investigated the occurrence of anthracite in the Silurian rocks of Central Bohemia, giving complete analyses of the coals from Radotin, Karlstein, Kuchelbad, and Pridoli.

Coal in Dalmatia.—A. König || discusses the mineral resources of Dalmatia, and points out the urgent need for a geological survey of the country. The principal products are asphalt and coal. The author has recently sunk a shaft 8 yards in depth and found asphalt containing 82 per cent. of bitumen. Among the other minerals of economic importance occurring in the country are bauxite, iron ore, and manganese ore.

* *Transactions of the Manchester Geological Society*, vol. xxvi. pp. 96-118.

† *Ibid.*, pp. 180-192.

‡ *Ibid.*, pp. 237-262, with 5 plates.

§ *Verhandlungen der k.k. geologischen Reichsanstalt*, 1899, pp. 348-362.

|| *Allgemeine Bergmännische Zeitschrift*, April 8, 1900, pp. 2-5.

Coal in Belgium.—In a discussion before the Belgian Geological Society* as to the probability of there being a northern extension to the Liège coal basin, M. Lohest† stated that he was of opinion that such an extension must really exist. He thinks that the Welsh coalfield may be looked upon as a continuation of that of Liège, and draws conclusions from the continuity between this coalfield and those of Manchester and Newcastle in proof of his theory as to a northern continuation of the Liège field itself. He points out that the Liège basin appears to extend into Holland, and is further of opinion that there must be coal between Visé and Lanaeken.

The question was also considered by A. Habets, who deals incidentally with the Westphalian coalfield, and considers that the new Belgian coalfield should be looked for to the north-west of Visé.

X. Stainier‡ has for some time been engaged in a comparative palæontological study of the coalfields of the South of England, Belgium, and Westphalia, and finds them to be so identical in all three basins as to make it far more than probable that all three were formed at the same time. He also thinks that a northern extension of the Belgian field may be looked for. The subject is also discussed by G. Velge,§ by Baron O. van Ertborn,|| and by H. Forir.¶

J. Smeysters** has prepared for the Paris Exhibition a detailed description of the Hainault coalfield. It is accompanied by a large folding map of the coalfield, showing the position of the various royalties.

The Pas de Calais Coalfield.—A. Simon†† describes the exploratory work carried on at the Liévin Colliery to determine the possible extension of the Coal Measures.

Coal in Holland.—F. Büttgenbach‡‡ refers to the question of the possible extension of the Belgian coalfields towards the coalfield of the province of Limburg, in Holland, and then discusses this latter field. Near Heerlen 300 tons of coal a day is now being wound from one

* *Revue Universelle des Mines*, vol. xlv. p. 277-282.

† *Annales de la Société Géologique de Belgique*, vol. xxvi. pp. 80-91.

‡ *Ibid.*, pp. 96-102.

§ *Ibid.*, pp. 91-96.

|| *Ibid.*, pp. 103-105.

¶ *Ibid.*, pp. 134-155.

** *Annales des Mines de Belgique*, vol. v. pp. 29-112.

†† *Bulletin de la Société de l'Industrie Minérale*, vol. xiii. pp. 777-791.

‡‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. 1 p. 81-82.

shaft, this latter being some 460 feet deep, the seam having a thickness of somewhat more than 6 feet. This coal resembles that of the Worm district, while the coal from the Domanial Colliery, near Kirchrath, is anthracitic in character. This was up to then the only colliery in Holland producing bituminous coal or anthracite. The seams at Heerlen probably belong to the upper group of seams of the Worm basin, and if this is so, a number of other seams may be looked for elsewhere in the Limburg district. Between Heeren and the very ancient colliery workings in the neighbourhood of Kirchrath another colliery working has been started at Schaasberg. Here a seam of coal 2 feet thick was met with at a depth of 470 feet. This coal, too, probably belongs to the bituminous coals of the Worm series. The Poetsch freezing process has been adopted in sinking the shaft at this colliery, and this is now progressing satisfactorily.

Coal in Russia.—J. Crankshaw * deals with coal-mining in South Russia, chiefly with the coal mines in the Jusowo district. The workable seams vary from 72 inches to 15 inches, but the average is about 24 inches, and the coal is generally of good appearance, light in weight, with a fibrous fracture, and is described as “fatty” coal. There is a large proportion of slack, but this does not appear to be of much importance, as the same price is got for the coal independent of size.

According to M. Verstraete,† the fuel resources of the Ural include wood, coal, peat, and oil. With each of these the author deals in detail. Its principal industrial fuel is wood, the others only play secondary parts at the various works in that district. The forests are still vast in extent, but they are unequally spread, having in places been largely destroyed by improper utilisation. The Ural district may be divided into three main parts, the north, the centre, and the south. Except in two provinces, the north possesses immense forests. These belong to the State, and are capable of ready exploitation. In the central district the forests are mostly in private hands, and are greatly impoverished. This is the district where smelting works have been longest established. The Southern Ural is the part poorest in forests. Those existing there belong for the most part to the Bachkirs, a nomadic race in summer, but working in the mines during the winter. The wood is cut in the spring, work being stopped about the month of

* *Transactions of the Manchester Geological Society*, January 12, 1900.

† *L'Oural*, Paris, Hachette et Cie., 1899.

July, when the workpeople return home. They return to the forests in September, and remain at work until November. A very few keep at work all through the winter. The winter is the transportation season. Marshes are then frozen, the ways are less bad, and the snow and ice admit of the transport of the cut wood, horse transport being employed. Various kinds of charcoal burning are employed, but the walled kiln is not likely to be very widely spread, it being easier to burn on the spot than to transport the wood to the kiln, even though the latter gives about 20 per cent. greater yield, but the charcoal produced is lighter and more friable. The trees in the Urals are not of large size.

Coal is found in the Ural in very large quantity, but it is unfortunately of poor quality. It is mined near the stations of Lounievka, Kizel, and Goubahka, on the line of railway from Perm to Ekaterinburg. A small anthracite colliery exists at Igorchinski. The Lounievka colliery possesses seven seams, believed to contain in all at least 800,000,000 poods of coal. The annual outturn is about 6,000,000 poods. The Kizel mines are still richer. They are three in number, and have an output of about 12,000,000 poods. The Goubahka collieries produce annually 4,500,000 poods. There is still another colliery, not far from Kizel, which yields about 800,000 poods. The production has considerably more than doubled within the last ten years. The coal contains:—

Volatile Matter.	Ash.	Sulphur.
27 to 30	17 to 23	2

When washed it yields a coke of poor quality.

Peat is found in the Urals in considerable quantities, but at present it is but very little employed in practice.

Coal in Nova Scotia.—E. Gilpin * describes the coals of Nova Scotia and their adaptability to the manufacture of coke for blast-furnaces. Reference is also made to oil, shale, and iron ore.

Coal in British Columbia.—G. F. Monckton † states that there are two coal-bearing districts near Kamloops Lake in British Columbia containing several seams about a foot or more in thickness, but apparently they are not of great value.

* *Proceedings and Transactions of the Nova Scotian Institute of Science*, vol. x. pp. 79-90.

† *Transactions of the Institution of Mining Engineers*, vol. xviii. pp. 295-296.

Coal in New Zealand.—Some notes on the coalfields of New Zealand * are given by J. Park. All the workable seams of coal are found in measures of Lower Eocene age, consisting of the following members in descending order :—(a) Oamaru stone (marine); (b) grey marly clays; (c) Waihao marly greensands (marine); (d) quartz, grits, and conglomerates; (e) fireclays with coal. Below the Amuri limestone coal is not found. Some particulars of the different coals are appended.

Coal in Queensland.—T. P. Moody † gives a sketch of the coal beds of Queensland, with extracts from various writers concerning the geology and nature of the Ipswich beds, the Burrum coalfield, the Bowen coalfield, and the Dawson and Mackenzie districts.

Coal in the Transvaal.—According to Bellet, ‡ when, in 1882, the Transvaal Government gave a concession for a blast-furnace plant, they drew attention to a deposit in the vicinity of Middelburg, the coal in which contained 13 per cent. of ash, but was otherwise of good quality. Another deposit was also mentioned to the south of Kool Junction. This now belongs to the Rand Coal Company. The seams worked are over 10 feet in thickness without partings, and contain only 6 to 8 per cent. of ash. In 1897 the output of coal is stated to have amounted to 1,667,752 tons.

Coal in Indiana.—The annual report of the Department of Geology in Indiana for 1898 contains a detailed account of the coal resources of that State, and adds much to the last report on that subject published in 1878.

Coal in Pennsylvania.—H. W. Althouse § gives some notes and sections of the Buckstone coalfields, Berlin basin, Somerset County, Pennsylvania.

Coal in Dakota.—In a monograph by L. F. Ward || on the Cretaceous formation of the Black Hills as indicated by the fossil

* Paper read before the Institution of Mining and Metallurgy, London, December 20, 1899.

† *Proceedings of the South Wales Institute of Engineers*, vol. xxi. pp. 353-358.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. p. 50.

§ *Engineering and Mining Journal*, vol. lxix. p. 291.

|| *Nineteenth Annual Report of the United States Geological Survey*, Part II. pp. 521-946.

plants, the fossil plants of the Hay Creek coalfield are described, and W. P. Jenney contributes a discussion of the stratigraphy from the palæontological standpoint.

Coal in the Richmond Basin, Virginia.—N. S. Shaler and J. B. Woodworth* describe the occurrence of coal in the Richmond basin, Virginia, and conclude that the central portions of the area most likely contain coal-beds in something like the measure in which they are exhibited at the margin.

Coal in Mexico.—According to E. T. Dumble,† in the search for coal outcrops on Calera Creek in Mexico, one of the slopes, driven on a supposed coal outcrop, opened out into a body of 3 feet of good coke, underlain by 2 feet of anthracite. Near by, the coke, which at 30 feet depth was 8 feet thick, at 130 feet depth was over 10 feet thick. Besides these two principal openings, which subsequently proved to be in the same bed, several other deposits have since been found, with thicknesses of from 2 feet to 4 feet. In almost every instance there is a close relation between the intrusive rock and the coke.

Coal in India.—T. H. D. La Touche‡ gives some further notes on the coal at Palana village in Bikanir State. The seam for some reason is very variable in thickness, ranging from 20 inches to 20 feet in a distance of 1600 feet.

F. H. Smith,§ in an account of the geology of the Mikir Hills in Assam, states that eight coal exposures were seen, but only two on the Longloi hill and in the Nambor river are of sufficient thickness to be of value, the first being 12 feet in thickness, and the second 7 feet. Assays are as follows:—

	Longloi.		Nambor.	
Moisture	5·36	3·88	3·14	9·40
Volatile matter . .	49·96	57·52	29·00	34·42
Fixed carbon . . .	25·32	25·40	15·24	26·32
Ash	19·36	13·20	52·62	29·86

Coal in China.—J. G. H. Glass, in a report|| to the Pekin Syndicate, deals with the coal and iron deposits in the provinces

* *Nineteenth Annual Report of the United States Geological Survey, Part II.* pp. 385-520.

† *Transactions of the American Institute of Mining Engineers*, September 1899.

‡ *General Report on the Geological Survey of India*, 1898-99, pp. 33-35.

§ *Memoirs of the Geological Survey of India*, vol. xxviii. pp. 71-95.

|| November 1899.

of Shansi and Honan in China, and states that large deposits of both coal and iron occur. At one native colliery worked by two 9-foot shafts 220 feet deep, 108 tons daily are raised by windlasses from very irregular workings. General Tsao Kai Chiong gives a number of particulars regarding the conditions and costs of coal-mining. The above-mentioned colliery and others are described in some detail by W. H. Shockley, with particulars of the anthracite and more bituminous coals encountered, and analyses of several coals ranging from 60 to 90 per cent. of fixed carbon are given by Riley, Pattinson, and Stead.

N. F. Drake * describes the coalfields around Tsé Chou, Shansi, China, and gives a number of sections and plans, together with photographic illustrations of the district. The geological relations of the district receive considerable attention. The workable coal, 22 feet in thickness, lies in one bed about 250 feet above a flint-bearing limestone stratum, but a little coal is found below it. Several mines are worked by the Chinese, and all the coal is anthracitic, ranging from 80 to 87 per cent. of fixed carbon. Several assays are given. A map showing the proposed railways is appended.

The Itschoufu coalfield, Shantung, China, is described by J. François.† Coal is found over an area of about $9\frac{1}{2}$ square miles in seams ranging from 3 to 100 feet in thickness, and has only recently been mined, but the operations are on a very primitive scale. Owing to water, there is no sinking over 100 feet in depth. Coke is made in holes 5 feet wide and deep in the earth, and rich red hæmatites are found in the neighbourhood.

Coal in Japan.—An interesting paper on the mining and metallurgical industries of Japan has been published by O. Vogel.‡ Formerly the deposits of precious metals were considered to be inexhaustible, a belief based on the accounts published by Marco Polo in the year 1270. In the seventeenth century the Dutch exported some £400,000 of silver yearly. Subsequently copper became the chief commodity. Ores were formerly mined in a very primitive manner. Adit levels were driven, and the ore was raised in baskets and sacks by women and children. Windlasses and other

* *Transactions of the American Institute of Mining Engineers*, Washington Meeting, February 1900.

† From a note to the *Société des Ingénieurs des Mines du Hainaut*, based on a communication to the *Montan Zeitung* by the explorer, Ernst von Hesse-Wartegg.

‡ *Mining Journal*, vol. lxx. p. 32.

devices for winding were quite unknown. Water was raised by inefficient hand-pumps. Considering the primitive appliances used, it is remarkable that several adits reached a length of 1000 feet and that depths of 600 to 800 feet were attained. Up to quite recent times the use of explosives was unknown. Fire-setting was frequently employed. Japan also possesses valuable deposits of coal. The mineral is a bituminous coal of recent geological age subject to spontaneous combustion. In the island of Amakusa anthracite is met with, and Japan has also large deposits of brown coal. The most important coalfield is that of the island of Kiutschiu, which furnishes 87 per cent. of the Japanese output. The principal colliery is that at Miike, which has been worked since the year 1468; it was formerly the property of the Government, but has now passed into the possession of the firm of Mitsui & Co., who are described as the Japanese Rothschilds. The output of this colliery is 2500 tons a day, or 1,000,000 tons yearly. The coal seam, which averages 8 feet in thickness, is in places over 20 feet thick. The miners are chiefly convicts from the penitentiary in the vicinity. The coal production of Japan rose from 2,000,000 tons in 1888 to 6,000,000 tons in 1897, an increase of 300 per cent. in ten years. At the same time the price of coal has risen 130 per cent. In 1895 there were 157 collieries in operation, the number of miners employed being 54,000. The exports of coal rose from 327,000 tons in 1882 to 975,000 tons in 1888 and to 2,500,000 tons in 1897. The Japanese coal is sent mostly to China, to Corea, and to Australia. The coal consumed in native factories has increased tenfold in amount since 1888—namely, from 146,000 tons in 1888 to 1,553,000 tons in 1898. Formerly charcoal was exclusively used.

A small sketch-map of Hokkaido has appeared,* showing the situation of the coal mines and their railway communication. The collieries worked by the Hokkaido company are those of Yubari, with two beds 25 and 4 feet in thickness; Sorachi, with ten beds ranging from 4 to 9 feet; Poronai, with four beds averaging 5 to 6 feet; and Ikushunbetsu, with four beds, each averaging 5 feet in thickness.

Coal in Persia.—H. Winklehner † gives an account of prospecting journeys for coal in the provinces of Persia bordering on the Persian Gulf. Coal is practically non-existent there, he states, though he found it in very small quantity in one place.

* *Engineering*, vol. lxxviii. pp. 767-768.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 645-646.

III.—CHARCOAL.

Charcoal-Making.—Fischer* shows that sawdust and shavings may profitably be converted into charcoal, if all the moisture is not expelled and the material is made into briquettes before treatment, if it is possible cheaply and rapidly to dry the sawdust by waste heat, and if carbonisation is effected at the lowest temperature (300° C.) in apparatus of large capacity.

The distillation of wood at the present time is discussed by F. A. Bühler.† Cheap wood is necessary, and consequently in Germany charcoal manufacture is no longer profitable.

By-Products of Charcoal-Making.—H. O. Chute‡ discusses the influence of the by-products of charcoal manufacture on the charcoal pig-iron industry. The effect of the wood and the charcoal supply on the situation of the furnaces is dealt with, and attention is directed to the growing use of retort charcoal and to the relative situations of the charcoal works and the blast-furnace.

IV.—COKE.

Beehive Ovens.—Illustrations have appeared§ of the Hemingway oven, which is of the beehive type, with arrangements for supplying heated blast.

W. G. Irwin|| refers to the importance of reducing the time of coking, and states that practically all the attempts made to reduce the time in the beehive oven have had no good results, and have only reduced the quality of the coke. Recourse must be had to the retort oven.

The conveyor designed by J. Muller leads the hot coke discharged from the ovens under water, and then to a sufficient height for loading into the railway vehicles.¶

F. C. Kieghley** gives a brief review of the history of Connellsville

* *Zeitschrift für angewandte Chemie*, 1900, pp. 192-197.

† *Ibid.*, pp. 155-165, with 25 illustrations.

‡ *Iron Age*, October 5, 1899, pp. 7-8.

§ *Ibid.*, January 18, 1900, pp. 13-15.

|| *Engineering and Mining Journal*, vol. lxi. p. 256.

¶ *Iron and Coal Trades Review*, vol. lix. p. 1127.

** Paper read before the Central Mining Institute of Western Pennsylvania; *American Manufacturer*, vol. lvi. pp. 216-217.

coke, and makes some general remarks on the present condition of the district. W. G. Irwin * similarly deals with this district.

E. M. Peters † discusses the relation between coke producers and consumers.

By-Products of Coke-Ovens.—An article dealing with modern forms of coke-ovens has appeared.‡ After dealing with United Kingdom plants on the Semet-Solvay system, the Otto-Hoffmann system is described. In Austria and Germany 2909 such ovens are now erected. These ovens up to three years ago were on the regenerative system, but this is no longer employed, a modified form of the oven without regenerators having given still better results. The necessary qualifications for a coke-oven are briefly mentioned, and then, continuing the description of the Otto-Hoffmann system, it is stated that, with a view to avoid irregularities in the temperature, each oven was at one time provided with double walls. This has now been abandoned, experience having shown that such double walls are unnecessary. At present the ovens are heated by a series of gigantic Bunsen burners, and it is evident that it is therefore possible by regulating the quantities of gas and air employed in the burners to vary the temperature of the oven at will, and that the temperature can also be made of an even and constant character throughout the whole length and width of the oven. The air used is not pre-heated before entering the oven, but still, by passing in a circuitous way to the burners, it is warmed considerably before it reaches them, and may even attain a temperature of 400° C. As a rule, enormous heat losses take place in coke-ovens by heating the ground on which they stand. In the case of the system under review this is not the case, the air required for the combustion being made to keep the bottom parts of the oven cool. The time required for completing the coking is about twenty-nine hours.

In no form of coke-oven are the oven walls absolutely air-tight, and this leads to losses in the working of the oven. In the Otto-Hoffmann system this danger is very largely avoided, as will be seen from the following analyses of the coke-oven gases from such coke-ovens at the Pluto Colliery :—

* *Engineering and Mining Journal*, vol. lxi. p. 350.

† Paper read before the Central Mining Institute of Western Pennsylvania, December 1899, through *Mines and Minerals*, vol. xx. pp. 321-322.

‡ *Stahl und Eisen*, vol. xix. pp. 1055-1060; 1 illustration.

	I.	II.
	Per Cent.	Per Cent.
Carbon dioxide	3·6	3·5
Carbon monoxide	6·7	7·2
Heavy hydrocarbons	2·3	2·1
Methane	32·9	33·4
Hydrogen	44·4	45·0
Nitrogen	10·0	8·7
Totals	99·9	99·9

The yield of by-products is correspondingly satisfactory, and the tar is richer in benzene and its homologues than is customary. Comparative analyses are shown in proof of this of two samples of tar, one made in a modern Otto-Hoffmann coke-oven and the other in a Brunck oven. The first had 57 per cent. of constituents that could be distilled off, and the latter only 47 per cent. These ovens yield more gas than they require for their own use. In the Ruhr district there is an excess of about 10 to 25 per cent. Even after the extraction of the by-products from the gas, it retains an illuminating power of 10 to 12 candles, while it has a calorific value of from 4200 to 4600 calories.

At the Preussen Colliery 160 Otto-Hoffmann coke-ovens are connected with a single plant for the collection of the by-products. This is consequently on a very large scale, the coke-ovens yielding annually when in full operation 240,000 tons of coke, 4200 tons of ammonium sulphate, and 11,000 tons of tar. The plant requires the use of two 100 h.p. engines, and one of these is operated by the waste coke-oven gas, the other being driven by steam. As a rule, only the gas-engine is in operation, the other being only employed at intervals. In conclusion it is pointed out that only two modern systems of coke-ovens have been widely adopted—the Otto-Hoffmann, chiefly in Germany, and the Semet-Solvay, chiefly in other countries. The yield of one of these latter ovens is stated to be from 1016 to 1244 tons a year, while that of the modern Otto-Hoffmann oven is placed at a minimum of 1500. The two ovens are compared, and the latter is considered the better from many points of view. In the Semet-Solvay oven the flues are horizontal, while in the Otto-Hoffmann they are vertical.

Another publication * contains a general review of the various kinds of coke-ovens in general use, but this review is little more than a brief epitome. With regard to horizontal coking-ovens, it is pointed out

* *Chemiker Zeitung*, vol. xxiv. p. 76.

that these are of two kinds, one of which has horizontal gas channels and the other vertical channels. In both of these, the less bituminous is the coal coked, the thinner must be the divisions separating adjoining chambers. The great change from older to modern methods has consisted in the abandonment of all systems of coking in which air could enter freely to the coal during the coking, and the introduction of methods for the collection of the by-products.

J. D. Pennock * discusses coke-oven by-products and their chemistry. The use of pyrometers for controlling the temperature in the flues is first referred to, and then a comparison is made between beehive and retort-oven coke as regards their behaviour and the yield and percentage of impurities present. The nature and amount of the ammonia, tar, gas, and other by-products are then dealt with.

The behaviour and recovery of nitrogen in coal distillation in the coke-oven, the blast-furnace, and elsewhere is dealt with by W. C. Anderson † and J. Roberts.

Weihe ‡ describes and illustrates the mechanical over-rope haulage at the coke-oven plant at Altenwald in the Saarbrücken district belonging to the Röchlingschen Iron and Steel Works.

At the Preussen Colliery of the Harpen Company a by-product coke-oven plant comprising 160 Otto coke-ovens is in course of erection. § A plant of sixty Otto coke-ovens of similar design at the Pluto Colliery yielded during the year ending July 1, 1899—coke, 90,093 tons; ammonium sulphate, 1480 tons; and tar, 3783 tons.

The new Otto by-product coke-oven with under-firing is described and illustrated by K. Hilgenstock. ||

The Kuhn electrically-driven coal-stamping machine, for compressing the charge in coke-ovens, is illustrated. ¶ This machine is in use at the Mathias Stinnes Colliery at Carnap, in the Ruhr basin, at a battery of Otto ovens.

W. L. Affelder ** describes and illustrates the plant of fifty Semet-Solvay ovens erected at Dunbar, Pennsylvania.

There have been installed at the Mieres Works two batteries of 24 Carvès coke-ovens arranged for the recovery of by-products. Each oven treats 6 tons of coal, and yields 4 to 4½ tons of coke in 48 hours.

* *Iron and Coal Trades Review*, vol. lx. pp. 649-650, 693-694.

† *Journal of the Society of Chemical Industry*, vol. xviii. pp. 1099-1106.

‡ *Glückauf*, vol. xxxv. pp. 849-853.

§ *Ibid.*, vol. xxxv. pp. 685-686.

|| *Ibid.*, vol. xxxv. pp. 977-982.

¶ *Ibid.*, vol. xxxv. pp. 957-959.

** *Mines and Minerals*, vol. xx. pp. 297-298.

Coal from the Baltasara Mine yielded 27·27 per cent. of volatile matter and 72·73 per cent. of excellent coke. The yield per ton comprised 5 lbs. of ammonia, equivalent to 18 lbs. of ammonium-sulphate, and 10 lbs. of benzol.*

The Use of Coke-Oven Gas for Illuminating Purposes.—

F. Schniewind † gives further particulars of the Otto-Hoffmann ovens erected at Everett for supplying Boston with illuminating gas. At the time 200 out of the 400 ovens were in operation, but the others were shortly to be started. The surplus gas is only taken during the first ten hours, and amounts to 2900 cubic feet per ton of coal. The tar and coke are of good quality.

A Dry Cooling Process for Coke.—In order to avoid the disadvantages due to the ordinary process of quenching coke by water, the Arnim Colliery Company of Planitz, near Zwickau, in Saxony, have introduced two systems of dry cooling. Either the coke to be cooled is transferred from the oven to a receiver with strong walls, the coke then being covered with some material that excludes the access of air, or an air-tight receiver is furnished in which the coke can be placed. In any case, the coke remains in the cooling receiver until another charge from the oven is ready. Illustrations of the plant are given.‡

V.—LIQUID FUEL.

The Origin of Petroleum.—G. Krämer§ and A. Spilker have examined the benzine extract of a diatomaceous mud under a layer of peat in the extinct lake near Ludwigshof, in the Weckmark district, and discuss the result of their researches in connection with the origin of petroleum.

C. Engler|| traverses the opinions advanced, and thinks that the arguments expressed by the authors as to diatomaceous origin are inconclusive. He adheres to his theory that petroleum was formed mainly by the decomposition of marine animal deposits.

* *Revista Minera*, vol. li. pp. 59-60.

† *Progressive Age*, vol. xviii. pp. 9-10; see also *Journal of the Iron and Steel Institute*, 1899, No. II. p. 356.

‡ *Iron and Coal Trades Review*, vol. lix. pp. 797-798.

§ *Berichte der Deutschen Chemischen Gesellschaft*, vol. xxxii. pp. 2940-2959.

|| *Ibid.*, vol. xxxiii. pp. 7-21.

A. S. Cooper * considers the different deposits of oil and asphalt in California, and the conditions surrounding them. An endeavour is made to trace the causes which produced these deposits and determined their situation, water circulation being taken as one of the main factors. Prospecting for petroleum and its valuation are also dealt with.

The Petroleum Industry.—Although the occurrence of combustible gases was known from time immemorial, the petroleum industry, in its modern sense, did not commence until the middle of the nineteenth century.† In 1857 the total output of oil in the United States was only 12 casks, or about 500 gallons, but in 1899 as much as 150,000,000 gallons of oil were imported into Germany alone. The total quantity of petroleum obtained in the world annually has amounted in recent years to about 5,000,000,000 gallons; of which, in 1899, some 2,300,000,000 gallons were obtained from the wells of the United States. In Russia the output was probably still larger, and as to the remainder of about 277,000,000 gallons, some 87 millions were produced in Austria, 72 in Sumatra, 30 in Java, 29 in Canada, 24 in Roumania, 15 in India, 8 in Japan, 7 in Germany, 3 in Peru, and 1 million in Italy. The question of the origin of petroleum has been long in dispute. The various theories that have been formulated in elucidation of this are briefly mentioned. The theory at present more generally accepted is that the petroleum is of organic origin.

The next point dealt with is that of the further treatment to which petroleum is subjected in its process of manufacture. The products obtained are very numerous, and the factories dealing with it may be divided into four main groups. These comprise those producing (1) benzine, (2) illuminating oils, (3) lubricating oils, and (4) paraffin. This general treatment of the raw oil may practically be divided into (1) the distillation process, and (2) the true refining process. Various improvements that have been introduced in them are briefly referred to. They include the use of superheated steam, and, in connection with the production of lubricating oils, distillation in a partial vacuum. The use of concentrated sulphuric acid in refining the so-called semi-manufactured distillation products appears to have been first introduced by Eichler at Baku about the middle of the sixties. Numerous suggestions have been made as to replacing

* "The Genesis of Petroleum and Asphaltum in California," *Bulletin*, No. 16, Californian State Mining Bureau, pp. 90, illustrated.

† *Chemiker Zeitung*, vol. xxiv. pp. 92-95.

the sulphuric acid by other agents, as well as the caustic soda used, by milk of lime, but these have in general failed to be adopted. The use, too, of the strongest possible sulphuric acid instead of the 93 to 94 per cent. acid does not appear to have been accompanied by much success. The methods employed for bringing about a perfect admixture between the oil and the acid include stirring appliances, compressed air, &c. These are briefly enumerated, and other details of manufacture drawn attention to. Some attention is then devoted to analytical matters in connection with petroleum, and then the Russian naphtha industry is passed in review. The question of transport is one of extreme seriousness for this industry. At present the Russian oil shipped is of the enormous quantity of nine thousand millions of litres (say 1,984,000,000 gallons), and this is moved chiefly by pumps, tank-waggon, and tank-steamers. The next source of petroleum that is dealt with is Galicia. The first workings for petroleum date back to about 1850. The first petroleum refinery of any importance that was established was erected in 1863, but new ones only began to be erected about twenty years subsequently. To-day there are about eighty oil refineries in Austria-Hungary. In 1871 the output of oil in Galicia was about 3800 tons, but the production increased steadily from year to year, with the result that in 1898 the quantity of oil obtained amounted to about 300,000 tons. In Galicia the oil is found chiefly in sandstone. The system of drilling adopted is usually the Canadian. In the refineries the oil passes from the oil reservoirs to the boilers. In these up to 100 tons of oil are distilled at a time with the use of superheated steam. Formerly the boilers used were much smaller in size. Continuous systems of working are only employed at a few works; wrought iron is chiefly used in the construction of the boilers, details as to which are given. In Russia petroleum residues are usually used for firing purposes, but in Galicia coal-firing is more generally employed. When the benzines and illuminating oils have been distilled off, the residues are got rid of and the boiler freshly charged. The condensation of the vapours takes place in water-cooled condensers. Occasionally the raw oil is used for cooling purposes, being in this manner pre-heated. The chemical purification takes place in agitators with compressed air stirring, sulphuric acid from 93 to 97 per cent. strength being employed. Fuming sulphuric acid is also occasionally employed. The cracking process is used in the treatment of the residues for the purpose of further splitting them up by pressure and

local superheating. Lubricating oils are largely made from the residues. Galician petroleum contains much paraffin, and this is separated out by crystallisation in the cold, freezing machines being employed for this purpose. The ammonia machines have given the best results. The petroleum refiner can increase at will either the quantity of illuminating oil he desires to make or that of the lubricating oil according to the state of the market. In the former case, he adopts the cracking process, while in the latter he distils the oil with superheated steam. This, however, leaves the paraffin in a colloidal form, in which it is very difficult to separate. It has, therefore, to be first separated by a freezing process. Details are given as to this separation of the paraffin.

A series of lectures by P. Dvorkovitz, at the City and Guilds Institute, deals with the history, origin, and geology, boring, physical and chemical constitution, distillation and refining, and uses of petroleum.

The depth of boring in relation to the productiveness of wells is discussed, and it is suggested that the depths of wells should always be given in regard to some fixed datum line.*

Petroleum in Europe.—An interesting article on petroleum in Europe has been published † by H. Neuburger and H. Noalhat. The output of the oilfields of the Carpathians is rapidly increasing. In Roumania, Bukowina, and Galicia, petroleum has long been known, but the industry has in the past been conducted with insufficient capital and with primitive equipment. Since 1880, however, a second oil-bearing horizon has been found at a depth of 400 yards, and a third at 500 yards. During the past two years a district hitherto unworked between Schodnica and Stanislovoff has been pierced by 1200 wells, and there are still areas as extensive and undoubtedly rich that have not yet been touched.

Petroleum in Italy.—An exhaustive memoir has been published ‡ by G. de Angelis d'Ossat on the occurrence of petroleum at Tocco da Casauria, in Abruzzo.

E. Cecchi-Mongarini§ has chemically examined the petroleum of Salsomaggiore and Ozzano in the province of Parma, and of Valleia,

* *Petroleum Review*, vol. i. pp. 701-702.

† *Le Mois Scientifique et Industriel*, 1900, p. 54.

‡ *Rassegna Mineraria*, vol. xi. pp. 258-261.

§ *Gazzetta chimica italiana*, vol. xxix. pp. 460-470.

near Piacenza, and finds that they consist of hydrocarbons of the naphthalene series.

Petroleum in Roumania.—The statistical report of the Minister of Agriculture, Industry, and Commerce of Roumania for 1898 gives particulars of the oil trade in Dambrovitza, Prahova, Buzeu, and Bacau, where altogether 13,417 tons of oil were produced. Particulars of the different wells are appended.*

A central electric generating station for supplying power to boring-rigs has been erected at Campina.†

A. O. Saligny ‡ has investigated in some detail the oils produced in Roumania, and gives a number of tables and statements embodying the results of his researches. The first table shows the physical properties of twelve samples of oil from Bacau, Buzeu, Prahova, Dambrovitza, and Ramon-Valcea. Analyses of different samples from the above and various other districts are given, together with distillation tests.

Petroleum in Russia.—A description has appeared § of the Guria or Ozourghetti oil-field in the province of Kutais, giving an account of the chief districts and of the wells sunk. An analysis of the crude oil, specific gravity 0·984, shows 40·1 per cent. of machine-oil, 13·65 of burning-oil, and 23·88 per cent. of pitch.

R. Zuber || gives a geological sketch of the oil-fields of the Apsheron peninsula, with a sketch map and sections.

Some details of the cost of boring in the Baku district have recently been given. ¶ The wells, as a rule, begin with 26 to 28-inch pipes, and finish with 16 to 14 or sometimes 10-inch pipes. The work is usually done by contract, at a fixed rate per fathom down to 700 feet, after which the cost is higher. In one instance the price is given at 70 to 90 roubles per fathom, and in one case the price paid per foot for the first 700 feet works out to about 25s. per foot, rising 3½d. per foot for each additional 70 feet for 420 feet, and then 7d. per foot in each 70 feet in the next 250 feet.

A medical committee was appointed in Russia to investigate the

* *Petroleum Review*, vol. i. pp. 603, 631, 659.

† *Ibid.*, pp. 663–664.

‡ *Chemisches Centralblatt*, 1900, p. 60; *Petroleum Review*, vol. ii. pp. 139, 175, 234.

§ *Petroleum Review*, vol. i. pp. 530–531.

|| *Ibid.*, pp. 660–661.

¶ *Neftianoe Delo*; *Petroleum Review*, vol. ii. pp. 33–34.

effect of the oil industries on the Volga on the fisheries of that river. It was concluded that some steps should be taken to prevent leakage of oil into the river.*

A description is published † of the petroleum pipe-line of the Trans-Caucasian railway from Michailovo to Batoum. The pipe-line is 138 miles in length, and has an internal diameter of 8 inches. It has a daily capacity of 215,000 poods, and has been built by the Government with a view to relieving the pressure on the railway.

It is stated that in 1899 twelve fires occurred in the Baku petroleum fields, destroying fifty-nine derricks of producing wells and wells in the course of being sunk.‡

The productions of the various oil-producing firms in Russia for 1898 and 1899 are given.§

The petroleum industry of Baku is described,|| and the Russian petroleum industry is reviewed by Wischin.¶

K. W. Charitschkoff has communicated to the Russian Chemical Society ** the results of his investigations of the composition of petroleum from Grosny. It contains the same organic compounds as American petroleum, but in different proportions.

A description has been published †† of the extensive petroleum deposits of the island of Saghalien, East Siberia, which appear to offer a promising field.

Petroleum in California.—According to W. L. Watts,‡‡ the California oil-fields which have been developed are situated at Los Angeles, Ventura, Santa Barbara, Kern, Kings, and Fresno counties. Oil-yielding formations have been traced throughout the Coast Range, almost from San Diego to Del Norte counties. North of San Francisco no oil-fields have as yet been developed, but prospecting wells are being drilled at several places. The most remarkable features in the recent history of the petroleum industry in California have been the development of the Los Angeles oil-field, the Summerland oil-field in Santa Barbara, and the oil-field of Coalinga in Fresno county. The Coalinga

* *Petroleum Review*, vol. ii. p. 127.

† *Dingler's Polytechnisches Journal*, vol. lxxxi. pp. 19-20.

‡ *Petroleum Review*, vol. ii. p. 17.

§ *Ibid.*, vol. ii. p. 145.

|| *Archiv für Eisenbahnwesen*, 1900, pp. 425-461.

¶ *Zeitschrift für angewandte Chemie*, 1900, pp. 313-318.

** *Journal*, vol. xxxi. pp. 552-514, 656-658.

†† *Organ des Vereins der Bohrtechniker*, 1900, No. 1.

‡‡ *Transactions of the American Institute of Mining Engineers*, October 1899.

oil-field is the most important yet developed in the border of the central valley of California. It is remarkable both for the amount and the quality of the oil which it has produced. Very productive oil-fields have also been developed at the Kern river and at McKittrick in Kern county. In the Los Angeles oil-field fully 1100 wells have been drilled within an area of about $2\frac{1}{2}$ miles in length and less than a quarter of a mile in width, and a western extension of that oil-field is rapidly being developed. The history and geology of the fields are dealt with, and the nature of the oil shortly described.

Petroleum in Texas.—F. C. Thiele * notes that three years ago petroleum was found at Corsicana. Since then some 400 wells have been sunk. The oil found resembles the Lima-Ohio oil, without, however, having the same unpleasant smell as is noticeable in the case of the oil from the Ohio-Indiana district. An analysis of the Corsicana oil showed it to contain :—

	Per Cent.	Specific Gravity.
Naphtha	10·8	0·710
Kerosene	54·5	0·796
Residue	34·7	0·905

The specific gravity of the raw oil is 0·8296. It closely resembles in some respects the Washington oil, but contains some asphalt and similar substances.

The oil-field of Texas is of large extent. At Nacogdoches oil is found which is of the high specific gravity 0·915. Its colour is black, and it contains much sulphuretted hydrogen. Very heavy oil is found at a depth of 250 feet in alluvial ground at Lour Lake. It has at 17° C. the specific gravity 0·963, and contains 20 per cent. of asphalt. It is excellent as a lubricating oil, and somewhat resembles the oils which are found near Wiene-Steinförde, in Germany. With regard to the origin of the oil, the presence of aromatic hydrocarbons and the absence of solid paraffin points to a vegetable origin, but, on the other hand, the presence of nitrogenous products and of a large percentage of sulphur lead to the assumption that the oil is of animal origin rather than vegetable.

In a paper read before the New York section of the Society of Chemical Industry,† C. Richardson stated that although the discovery of petroleum in Texas was made in 1894, the rapid development of

* *American Chemical Journal*, vol. xxii. pp. 489-493.

† *Journal of the Society of Chemical Industry*, vol. xix. pp. 121-123.

the oil-fields about Corsicana indicated that Texas might soon be a competitor in oil production with the fields of the Central-Western United States. Analysis of the product showed it to be richer in some respects than the California oil.

Petroleum in Burma.—G. E. Grimes * gives a geological map and describes the geology of parts of the Myingyan, Magwe, and Pakokku districts, and includes much about the Yenangyat and the Yenangaung oil-fields and their extensions, giving particulars of the various oil sands that occur.

Petroleum in Borneo.—Some illustrations have appeared of the oil districts of Borneo, showing the boring plant, refinery, quays, &c.†

Petroleum in Persia.—H. Winklehner ‡ observes that the occurrence of petroleum in Persia has been known from very early times. A hot spring occurs in the neighbourhood of the town of Schushter, and this carries oil on its surface. This spring was not investigated by the author, but the oil is skimmed off the surface by the owners of the spring, and sold by them for illuminating purposes. About 60 to 90 quarts of oil a day are stated to be obtained. At Daliki, some fifty miles from Bushir on the Persian Gulf, a very hot sulphur spring exists at the foot of a range of hills consisting of calcareous marl, limestone, and gypsum. The country is very shattered, and the lie of the beds very various and irregular. Various bore-holes were put down to shallow depths in this neighbourhood in the eighties, and subsequently two other bore-holes were put down to a maximum depth of 621 feet at great expense. The heat in the summer was far too high to enable any operation to be continued, the shade temperature at nine in the morning on a day the author visited the plant being over 118°, and it rose to over 125° at two in the afternoon. Much gas was met with, but very little oil, and there was no practical result. The oil struck was so thick that not even pumps succeeded in getting it out of the bore-hole. It was a kind of pitch with a naphtha-like smell. Despite the want of success in this particular instance, the author thinks that later on other attempts may lead to practical results, though he considers that it will be some time before any more money is risked on such an undertaking.

* *Memoirs of the Geological Survey of India*, vol. xxviii. pp. 30-54.

† *Petroleum Review*, vol. i. pp. 689-696, with plates.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 629-633.

Another occurrence of petroleum was noticed by the author in the vicinity of Minab, in the province of Bender Abbas. Here he found a spring smelling strongly of hydrogen sulphide, and carrying numerous drops of oil on its surface. The petroleum was similar to that observed at Daliki, yellow in colour and of an aromatic odour. The stream comes from a fault in limestone, and had a temperature in May of 84° F. An earthquake is said to have taken place here, and considerable quantities of oil are stated to have then appeared. Another occurrence of petroleum is on the island of Kishim, in the Persian Gulf. Here again hot springs show oil. A bore-hole was put down, but unsuccessfully. The author considers that no sufficient proof exists yet either one way or the other as to the presence of petroleum in paying quantities along the Persian Gulf.

Ozokerite in Galicia.—A report by J. Holobek on the ozokerite industry of Galicia has recently been issued by the Austrian Minister of Agriculture. The history of the industry is traced and its present condition is dealt with, a number of photographic and other views being given. The methods of mining, the geological distributions, and the origin of the material are also dealt with.*

On February 21 new regulations came into force in the Galician ozokerite districts, their object being to render impossible the dangerous and extravagant methods of mining hitherto employed. Ozokerite mining dates from 1864, and in 1898 the industry afforded employment to 5413 men, and represented an output of 7758 tons.†

The ceresin industry was formerly specifically Austrian, but now its chief centre is Germany.‡ The only countries now producing it are Germany, Austria, and Russia, with one single small plant each in France and Italy. The raw material is still ozokerite, which is found in workable quantity exclusively in Galicia, where some 8000 tons are mined annually. The ozokerite as mined is assorted according to quality, melted in open boilers and freed from water, cast into moulds, and then brought into commerce in pieces each of which weighs about 77 lbs. These are divided into six or more different sorts. The material in which the ozokerite occurs is a hard marl (*Lehmerde*) in which considerable quantities of ozokerite also occur in a finely divided form. This marl, which is known by the name of Lepp, is

* *Petroleum Review*, vol. ii. pp. 160, 197, 225, 254.

† *Mining Journal*, vol. lxx. p. 281.

‡ *Chemiker Zeitung*, vol. xxiv. pp. 94-95.

dried, crushed, and treated in the Merz extraction apparatus. The ozokerite directly obtained in this way is very clear and hard, and is useful in this form for several purposes. From a chemical standpoint the manufacture of ceresin is on the same level now as it was thirty or forty years ago, though great improvements have been made in technical matters. The refining is still done with sulphuric acid, and all other methods have decidedly proved failures. This is the more to be regretted, as from 15 to 20 per cent. of a costly material is destroyed in order to obtain the remaining 80 or 85 per cent. in a commercial form. The method of treatment is as follows:—A preliminary melting may be made in open boilers, but usually the ozokerite is merely broken into small lumps and then charged into the acid pots. These are cylindrical in form, and are made of weld-iron plates, with occasionally a cast-iron bottom. Before the ozokerite is charged into them, the necessary quantity of paraffin is first added. As soon as all the wax has been melted, the stirrer is set going and the heat increased. When the temperature reaches about 120° C. the sulphuric acid is added. This acid is of 66° Bé. (that with 97 to 98 per cent. monohydrate is better), and its quantity varies according to the grade of ceresin that is required. It is also dependent on the quality of the raw ozokerite under treatment. When all the acid has been added to the wax, the heat is again raised, and the temperature finally raised to 180° C. At this temperature the whole of the sulphur dioxide resulting from the decomposition of the sulphuric acid escapes rapidly and completely. When all the sulphurous acid has been driven off, the firing is stopped and the "pulverisation" stage commences. For this purpose the residues from ferrocyanide manufacture are employed. The new methods which have been of late years introduced for the manufacture of ferrocyanide have made this decolorising residue more and more scarce. A material which was formerly valueless, and then sold for two or three shillings, now costs 20s. to 25s. for the same quantity. In place of this powder other substitutes are now being used. When some 5 to 10 per cent. of the material has been added, the stirrer is kept in motion for from one to two hours, and the wax is then ready for "filtration" or the "press." Filter-presses are now employed. The colouring materials used subsequently are referred to, and the various adulterations likely to be added to the wax are also mentioned. As much as 70 per cent. of colophonium is sometimes met with, and in Russia 10 per cent. of the heaviest mineral oil is also added. Paraffin,

stearine, and Japan wax are also used for this purpose. The press residues, which come from the presses in the form of cakes, readily fall apart into a pulverulent mass. They are mixed with shavings and then extracted with benzine. More ceresin is obtained in this manner, and is used in a way the author describes.

The Boryslav mines are described by D. Henry,* and the petroleum industry of Galicia by L. Szajnaha.†

Asphalt.—S. F. Peckham ‡ discusses the composition of parianite or Trinidad pitch, but admits that he fails to come to any conclusion. However, he gives various particulars as to the effects of different solvents. In the course of the discussion on this paper, H. Endemann and many others dealt with the analysis of asphalts.

A. Lakes§ gives a few notes on the asphalt deposits of California.

Oil Shale in Sweden.—At a meeting of the Swedish Technological Society, Hans von Post || read a paper on the utilisation of alum shale as fuel for industrial purposes. It is a bituminous and pyritic clay shale, widely distributed in the Swedish Silurian strata. Shale from Degerhamm gave on analysis the following results :—

Moisture	.	.	.	.	.	.	.	.	.	1.42
Carbon	.	.	.	.	.	.	.	.	.	11.21
Hydrogen	.	.	.	.	.	.	.	.	.	1.22
Sulphur	.	.	.	.	.	.	.	.	.	9.64
Nitrogen	.	.	.	.	.	.	.	.	.	0.37
Carbonic acid	.	.	.	.	.	.	.	.	.	0.51
Sulphuric acid	.	.	.	.	.	.	.	.	.	0.32
Ash	.	.	.	.	.	.	.	.	.	75.37

Owing to the high percentage of ash, a special form of step-grate is necessary for burning the fuel. The author is of opinion that this shale might advantageously be used in lime-burning, in Portland cement manufacture, and in brickmaking.

Brown Coal Tar Industry.—The brown coal tar industry belongs purely to Saxony.¶ This is due to the fact that the only brown coal which has so far proved suitable for this industry is the earthy lignite

* *Bergbau*, 1900, No. 22.

† *Oesterreichische Chemiker und Techniker Zeitung*, 1900, No. 6.

‡ *Journal of the Franklin Institute*, vol. cxlix. pp. 161-193.

§ *Mines and Minerals*, vol. xx. pp. 108-109.

|| *Teknisk Tidskrift*, vol. xxix. p. 55.

¶ *Chemiker Zeitung*, vol. xxiv. p. 95.

found in the neighbourhood of the towns of Halle, Zeitz, and Weissenfels. Of the 23 million tons of brown coal mined annually in the Halle district, about 1·5 million tons are submitted to this treatment, the remainder being put on the market in the form of briquettes for fuel purposes. The industry in question only dates back to about the year 1850. Now, however, there are some forty works, with 1200 retorts, making tar and coke, and fourteen mineral oil works, which during the course of a year work up about 600,000 tons of the tar so obtained, paraffin and all kinds of brown coal tar oils being produced. The cast-iron retorts formerly employed have been replaced of late years by vertical cylinders made of fire-resisting materials.

Vacuum distillation has replaced the older methods, and freezing machines are now used instead of waiting for the cold of winter to cause the crystallisation. Of the products, the hard paraffin is used for candles and the softer for matches, &c. The solar oil and other products are also briefly referred to, and their uses stated.

VI.—NATURAL GAS.

Natural Gas in Indiana.—The Annual Report of the Department of Geology in Indiana for 1898 contains a long report by J. S. Leach on the supply of natural gas in that State. The undeveloped territory is becoming much smaller, and throughout the gas-fields the pressure has fallen rapidly. In 1895 the average pressure was 264 lbs., and in 1898 it was 181 lbs. Salt water is encroaching in all the bore-holes.

—ARTIFICIAL GAS.

Gas-Producers.—In some notes on the use of gas as fuel it is shown that the average loss of heating power by using coal in a producer amounts to about 10 per cent., and that this loss may be reduced by selecting certain kinds of fuel.*

Illustrations and plans have appeared of a 400 horse-power gas-producer plant for gas-engine work. It consists of two 7-foot revolving bottom producers, with Bildt automatic feeders, heat economisers,

* *Iron and Coal Trades Review*, vol. ix. pp. 205-206.

scrubbers, &c. The gas is made from "rice" anthracite, and averages 141 heat units per cubic foot.*

In the course of an article by E. Niebuhr† on gas motors, the amount of work done in the world by steam-engines is stated to be 15,000,000 horse-power. The progress effected in the economy in fuel is shown by the following details of coal consumption:—

Year.	Type of Engine.	Coal Consumption— lbs. per horse-power per hour.
1700	Savery's atmospheric	31.0
1768	Watt's low pressure	8.8
1801	Evans' high pressure	6.6
1804	Woolf's two cylinder	4.4
1850	Compound	2.2
1875	Triple expansion	1.8
1895	Triple expansion	1.5
1899	Triple expansion with superheated steam	1.4

According to H. Braune,‡ efforts have of late been made in Swedish open-hearth works to introduce the use of so-called "uncondensed" gas. The fuel is air-dried wood, or, still better, wood that has been dried in an oven. Good results are obtained with such dry wood, but if the wood is green, then a certain quantity of coal has to be mixed with the wood to obtain a suitable gas. The author draws attention to the possible use of peat in place of wood. Many kinds of peat contain very little sulphur, and what is so contained can be considerably diminished in quantity by suitable treatment. The author remarks on the criticisms that have appeared about the use of peat in this way, and points out how important such an application of peat would be if it proves capable of satisfactory direct use in open-hearths.

Large works have been established near Rostock for the collection of ammonia by treating peat according to a patented process, but so far no great success appears to have attended the process.§

Water-Gas.—Illustrations have appeared|| giving a section and elevation of the Dellwik-Fleischer water-gas producer in which water-

* *Iron Age*, October 26, 1899, pp. 1-3.

† *Timar's Rundschau*, March 3, 1900.

‡ *Wernländska Annaler*, 1899, pp. 57-59.

§ *Chemiker Zeitung*, vol. xxiv. p. 7.

|| *Engineering*, vol. lxix. pp. 118-119. See also C. Dellwik's paper in this volume.

gas is produced during fifty minutes and waste gas during ten minutes in the hour when the heating takes place. The product is stated to be nearly 40 cubic feet per pound of coke. Some instances of its use are given, and it is added that over thirty of this type of producer have been built.

J. E. Dowson * gives the results of some recent installations of his producer used in conjunction with gas-engines for producing power for driving dynamos and for various purposes. The gas is compared with ordinary illuminating gas and with steam much to its advantage.

A plan and some illustrations have been published † of the water-gas plant at Buffalo, New York, where two million cubic feet of gas are made daily.

J. Daniel ‡ gives a historical review of the manufacture and properties of water-gas; and the theory of the water-gas process is dealt with by Strache and Jahoda.§

VIII.—COAL-MINING.

Deep Boring.—In a paper read before the International Boring Congress, A. Fauck referred to improvements in deep boring methods, which consists in increasing the rapidity of the blows, in diminishing the height of fall, and in simplifying the construction of the apparatus by doing away with the “free-fall” portion. The water at the bottom of the hole is found in practice to interfere considerably with the efficiency of the drill when there is a considerable falling height, but this is much less when very slight falling heights are employed. The author deals generally with the subject of deep boring.

An important paper on deep boring in the recent formations of Sweden has been written by G. Nordenström,¶ in which he advocates putting down bore-holes in the Swedish coalfield to a depth of 2000 yards. He gives some interesting details of the cost of deep boring.

* *Proceedings of the Cleveland Institution of Engineers*, 1899, pp. 129-180.

† *Progressive Age*, vol. xviii. pp. 6-9.

‡ *Annales des Mines de Belgique*, vol. v. pp. 113-138.

§ *Journal für Gas-Beleuchtung*, 1900, pp. 354-367.

¶ *Stahl und Eisen*, vol. xix. p. 1184.

¶ *Teknisk Tidskrift*, vol. xxx. pp. 30-34.

In Sweden in 1889 the price to a depth of 110 metres was 14 kronor per metre. In other countries the prices charged per metre by the English Diamond Boring Company and by the German firm Schiedmann & Co., are as follows :—

Depth.	Diamond Boring Company.	
Metres.	£	Francs.
1-400	10	250
400-500 . . .	21	425
500-600 . . .	25	630
600-700 . . .	29	735
700-800 . . .	33	840

The investigation of the earth's crust by means of deep bore-holes forms the subject of a paper by E. Gail.*

Shaft Sinking.—G. Peace † describes the sinking of No. 3 Nook Pit by the Astley and Tyldesley Coal and Salt Company, and gives a detailed section of the sinking. No particular difficulties were encountered.

With the aid of large coloured plates, C. Wurst ‡ gives a detailed account of the shafts of the Vereinsglück Colliery at Olsnitz, and describes the method adopted for repairing No. 11 shaft.

At Ougrée, in Belgium, concrete has been used for lining a colliery shaft. The cement used was made from blast-furnace slag and sandstone from stone drifts in the colliery. It consisted of 55 per cent. of sandstone, 12·5 per cent. of cement, and 32·5 per cent. of broken slag. According to J. Linet, § the speed of sinking and walling together with concrete is 29 per cent. more than with brick lining, while the saving in wages is 82 per cent., and in the cost of materials 148 per cent.

The methods of sinking through heavily watered strata || are discussed by R. Robinson, especially as regards tubbing.

J. Keen ¶ gives a further description of the sinking of two shafts

* *Organ des Vereins der Bohrtechniker*, 1900, No. 4.

† *Transactions of the Manchester Geological Society*, February 1900.

‡ *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1899, pp. 95-104.

§ *Revue Universelle des Mines*, vol. xlviii, pp. 1-16.

|| *Journal of the British Society of Mining Students*, vol. xxii, pp. 47-51.

¶ *Transactions of the Midland Institution of Mining Engineers*, and also *Transactions of the Manchester Geological Society*, vol. xxvi, pp. 122-156, 159-161.

through heavily-watered strata at Maypole Colliery, Abram, near Wigan.

L. Petit * describes the sinking of a pair of shafts through heavily-watered ground by the Kind-Chaudron method.

A. Demeure † describes the Kind-Chaudron process as adopted at the Bois-du-Luc Collieries for sinking two shafts $13\frac{1}{2}$ feet in diameter. The sinking was carried on by ordinary means to a depth of about 140 feet, when wet ground was encountered, and a platform was erected at a depth of 108 feet for manipulating the rods, which were made in lengths of 184 feet to reduce the number of joints. A single trepan was used, the advance borer not being employed, and it weighed 66,000 lbs. To clear out the spoil a new form of dredger with a bucket chain was employed, the chain being driven by gearing from the rodding.

An illustration ‡ has appeared of McCulloch's frame for carrying the drills when sinking round shafts.

De Serres § describes a movable platform for use in lining a shaft during sinking operations.

A. Lukaszewski || describes an arrangement at a colliery at Boryslaw for emptying the skip used when sinking. At the head of the shaft the skip is received in a frame which tips sideways, so that the contents are discharged automatically. At the bottom of the shaft the guides were temporarily lengthened by attaching heavy chains.

Winding Appliances.—An article dealing with winding from deep mines which has recently appeared ¶ gives plans and elevation of the machinery built for the Dolcoath Mine in Cornwall, in which the whole machine traverses, carrying the drum laterally to avoid angling of the rope. The leading dimensions of the Tamarack engine are also given.

An illustration ** is given of the winding drum at the Atlantic Mine, Michigan. It is of double conical form, with a cylindrical portion in the centre, wide enough to carry 12 coils. The large diameter in the centre is 25 feet 4 inches, and the drum tapers off at each end to

* Paper read before the Société des Ingénieurs des Mines du Hainaut.

† *Iron and Coal Trades Review*, vol. lix. pp. 899-901.

‡ *Ibid.*, vol. lx. p. 751.

§ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 141-143.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 93-94.

¶ *Engineer*, vol. lxxxix. p. 288.

** *Engineering and Mining Journal*, vol. lxviii. p. 733.

12 feet. The total face is about 22 feet, and it is grooved for $1\frac{1}{4}$ -inch rope. The capacity of the hoist is 6000 lbs. ore, raised at 3400 feet per minute, running in balance; the total load unbalanced being 22,000 lbs. The maximum depth is 4000 feet and the inclination of the shaft is 55° from the horizontal. This engine can be reversed by steam.

A method for calculating the size of winding engines is given.* The diameter of the cylinder is determined from the average speed of hoisting.

Illustrations † have appeared of an old single vertical cylinder engine built in 1844 in the Ostrau-Karwin district, and driving a winding drum through spur and bevel gearing.

In order to gain information on the question of the relative superiority of compound and non-compound engines for winding in mines, J. Divis ‡ has carried out a series of comparative tests with a converted compound engine at the Rudolf shaft, Prizbram, and a similar non-compound engine at the Segengottes shaft. The results are tabulated for the experiments under several different conditions, and the conclusion drawn from the whole series is that the all-round saving of steam effected by the compound type of engine averages 12 per cent.

G. W. Westgarth § has not been able to find any manual which gives in detail the most economic lines for the position of the drum in relation to the position of the pulley, and the object of this paper, as far as actual data to hand will enable him to do so, is to submit such lines as he believes will be found to be a close approximation to the most economic ones, from the rope point of view, for the relative positions of the drum and pulley for pits from 100 to 1200 yards winding depth. It is most advantageous for the rope to pass over the pulley in the longest possible arc, and therefore the drum should be placed at some distance below the pulley. Particulars of the sizes of the ropes, drums, and pulleys, and of the distances and angles involved and of the work done, are tabulated for thirteen collieries. The best results are plotted in diagrams, and a further diagram shows the angles, sizes, &c., for different depths.

The Bruay Mining Company, Pas-de-Calais, has put down new

* *Mines and Minerals*, vol. xx. pp. 379-380.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 147-152, 161-169.

‡ *Ibid.*, vol. xlvii. pp. 605-607.

§ *Proceedings of the South Wales Institute of Engineers*, vol. xxi. pp. 340-352.

shafts and installed machinery of the most complete and modern type. It is intended to raise 3000 tons of coal daily or 900,000 tons annually from a pair of shafts. The entire plant is described in great detail, with the aid of numerous plates, by M. Sohlm.*

W. Bentrop† describes a new arrangement for upcast ventilating shafts fitted with winding appliances.

A winding drum with tangential arms, built at the Blanzky Colliery, is described by P. Perroy.‡

The results of some tests of various kinds of colliery engine-packings have been published.§

The Teague automatic expansion gear for winding engines is described by G. E. J. McMurtrie|| in some notes on "Some Steam Economics."

E. Tomson¶ describes his automatic retaining device for trucks in cages, &c.

Steinhoff** describes an improved form of the Hoppe safety-catch for cages, as tested at the Paulus-Hohenzollern Colliery at Beuthen.

A safety-lock for mine cage doors, devised by G. Gotthardt and in use at several German collieries, is illustrated.††

Illustrations are given ‡‡ of the safety-keps devised by S. Smith. The cage in its ascent strikes trigger-gear which throw out the props, which have slanting edges above their shouldered portions.

Steel Head-Frames.—A number of illustrations have appeared §§ to show nine different steel head-gears erected at various collieries in Pennsylvania. The principal dimensions are given, and also the specifications for two of them.

Winding-Ropes.—R. Peele ||| gives some general notes on the construction and use of winding-ropes.

* *Bulletin Technologique*, 1899, pp. 1039-1146.

† *Allgemeine Bergmännische Zeitschrift*, 1899, No. 5.

‡ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1898, pp. 196-202; *Colliery Guardian*, vol. lxxix, pp. 158-159.

§ *Iron and Coal Trades Review*, vol. lx, p. 259.

|| *Journal of the British Society of Mining Students*, vol. xx, pp. 59-75.

¶ *Allgemeine Bergmännische Zeitschrift*, 1899, No. 5.

** *Zeitschrift für das Berg-, Hütten-, und Salinenwesen im preussischen Staate*, vol. xlvii, pp. 315-323.

†† *Glückauf*, vol. xxxvi, p. 401.

‡‡ *Engineer*, vol. lxxxix, p. 34.

§§ *Mines and Minerals*, vol. xx, pp. 292-294, with plates.

||| *Ibid.*, pp. 351-353.

F. Soule * states that E. H. Benjamin has begun, in co-operation with the testing laboratory of the University of California at Berkeley, a series of tests of steel wire cables, and is endeavouring to obtain pieces of cable, both new and old and worn, from every deep mine of importance on the Pacific Coast, together with all the data obtainable concerning their manufacture and particular use. Pieces from each sample will be broken in the laboratory, and, as far as possible, the effects of winding around drums or pulleys, of sudden starting and stopping when loaded, of heavy shocks, and of the general wear and tear of the cables, will be ascertained by these tests.

The Marchienne Collieries, in the Charleroi basin, are stated by Ghysen † to have reached a depth exceeding 3300 feet, while one shaft is nearly 3600 feet in depth. In the lower levels the temperature reaches 28° C. Details are given as to this colliery and its appliances. Each wire rope used lasts about fourteen months. They are flat, and diminish in size with depth. About 700 tons of coal is wound per day.

Underground Haulage.—H. L. Auchmuty ‡ gives some notes on the permanent way for underground use, dealing with the sizes of rails, points, sleepers, methods of laying rails, and preparing the bed, &c.

H. Rhodes § deals with the transmission of power from the surface by the use of slow-moving belt-ropes in the shaft, and considers the engines, spur-gearing, driving and guide pulleys, clutches, straining-gear, and ropes. Illustrations of various types are given, and a tabulated statement of eight plants is appended.

N. Hutchings || describes the over-rope haulage at collieries near Pratt City, Alabama.

J. Treptow ¶ describes the chain and rope haulage at the collieries of the Zwickau-Oberhohndorf Company.

The chain and rope haulage at the Rhein-Preussen Colliery, Rhenish-Prussia, is described with the aid of a plan and other illustrations. **

H. Ghysen †† discusses the use of pulleys and brakes and of fences

* *Transactions of the American Institute of Mining Engineers*, September 1899.

† *Annuaire de l'Association des Ingénieurs Sortis de l'Ecole de Liège*, 1899, vol. xii. p. 10.

‡ *Mines and Minerals*, vol. xx. pp. 337-340.

§ *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 432-443.

|| *Mines and Minerals*, vol. xx. pp. 251-252.

¶ *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1899, pp. 43-69.

** *Glückauf*, vol. xxxv. pp. 809-812.

†† *Bulletin de l'Association des Ingénieurs Sortis de l'Ecole de Liège*, vol. xxiv. pp. 16-17.

on self-acting inclines, and describes various forms used on the Continent.

I. Thomas* describes a check or guard placed on the inside of sharp curves on the engine planes at Caeran Colliery, Maesteg. Curved timbers with intermediate pulleys form the check.

R. Peele† discusses the conveyance of compressed air in pipes, especially in reference to their size, and gives the formulas employed. The same author also ‡ deals with the advantages of two-stage compressors.

Some illustrations of colliery locomotives have appeared,§ with their leading dimensions. Figures of one or two very early locomotives are also given.

J. Kersten|| describes steam locomotives, electric locomotives with trolley, electric locomotives with accumulators, and locomotives working with benzine for underground use in Belgian collieries. Examples are given of each form, and the cost of haulage by the electric locomotives is given as about 1½d. per ton mile, and of the benzine machine at ¾d. per ton mile. The 8-horse power benzine locomotive is 10 feet long, 4 feet 5 inches wide, and 6 feet 7 inches high, including the cab, weighing 3·3 tons in running order; and that of 6-horse power is 8 feet 2 inches long, 3 feet 6 inches wide, and 3 feet 7 inches high, weighing 2·4 tons in running order, while the width of this engine may be reduced to 2 feet 11 inches when it has to run in narrow roads.

The recent installation of electric locomotives for underground haulage at the Norton Collieries, Virginia, is described.¶

Illustrations have appeared of a benzine locomotive for underground use. Its construction and use is discussed by E. Braun.**

Electricity in Mines.—J. P. Jackson and F. F. Thompson †† deal with the electric transmission of power, especially in soft coal mines, under two heads:—(1) Direct currents for haulage and other power;

* *Journal of the British Society of Mining Students*, vol. xxii. pp. 94-95.

† *Mines and Minerals*, vol. xx. pp. 135-136.

‡ *Ibid.*, pp. 281-282.

§ *Iron and Coal Trades Review*, vol. lx. pp. 645-647, 696-698.

|| *Annales des Mines de Belgique*, vol. iv. No. 4.

¶ *Engineering and Mining Journal*, vol. lxix. p. 379.

** *Zeitschrift für das Berg-, Hütten-, und Salinenwesen im preussischen Staate*, vol. xlvii. pp. 374-381.

†† Paper read before the American Institute of Electrical Engineers, Boston, June 1899.

(2) Direct currents for haulage, and polyphase currents for other power. The use of direct-current machinery for pumping and fans has not been found satisfactory in many instances, and the second system, that using direct and polyphase currents, has the inherent disadvantage of requiring the installation of two distinct and separate sets of generators and wiring. Examples of some plants in Western Virginia and elsewhere are given.

Electrical transmission of power in mines is discussed by A. Bloemendal,* and the plant at various European collieries is described and illustrated.

S. F. Walker† deals with the form and method of suspension of electric conductors for power and light purposes in shafts. This subject is also dealt with by G. W. Bousfield.‡

Coal-Cutting Machinery.—H. Davis§ describes machines for coal-cutting with a reciprocating or punching action. The type consists of an air cylinder with valves and cushions and a piston carrying the pick. The cylinder has two handles in rear, and is mounted on a pair of wheels. The machine is placed on a board with a trestle at the far end, and the operator sits behind on the board and directs the blows of the machine. The position of the workman is so arranged that he himself does not receive any shock. The number of strokes per minute is about 180, depth of holing 5 feet, and sometimes 6 feet, the former being better for working. Eighty feet of face 5 feet under should be done in eight hours.

Some power curves for coal-cutting and haulage machinery have been published.||

A list showing the collieries which have adopted coal-cutting machines in Great Britain has been published.¶ About seventy-five names are given.

Rock-Drilling.—Four illustrations drawn to scale have been published,** showing the improvements introduced in the Heise hand-boring machine. Excellent results have been obtained with this machine in shale and in sandstone.

* *Stahl und Eisen*, vol. xix. pp. 1066-1079.

† *Colliery Guardian*, vol. lxxix. pp. 399-400.

‡ *Ibid.*, p. 513.

§ *Transactions of the Institution of Mining Engineers*, December 1890.

|| *Iron and Coal Trades Review*, vol. lx. p. 28.

¶ *Ibid.*, vol. lx. p. 791.

** *Glückauf*, vol. xxxvi. pp. 284-285.

S. Bates * describes the driving of a stone drift 5145 feet in length, 11 feet wide, and $6\frac{1}{2}$ feet high at the West Wylam Colliery with the aid of the Cranston percussive drill, compressed powder and gelignite being used as the explosive. A section of the strata is appended.

Timbering in Mines.—J. Dickinson † discusses the nature and strength of pit props and the method of setting them, which is of even greater importance than the strength. Props are usually set at right angles to the bedding, but generally there is some variation, and this should be allowed to counteract side thrusts. Setting the butt end upwards or downwards is also dealt with, both being advantageous under certain circumstances. The question of drawing timber is also discussed. The paper to a considerable extent deals with historical matters, and it gives a review of the investigations of the authorities on physical properties of wood and on propping mines. A number of tables are appended giving the strength and other properties of wood.

According to W. H. Hepplewhite ‡ the problem of preventing props being broken, when working under normal conditions, is, to a great extent, solved by simply thinning or tapering one end of the prop, allowing it to yield to the depressing roof, so that, instead of the prop breaking, the tapered end will “burr” or “fuzz” up the taper. If the normal depression of the roof is 6 inches 6 feet back from the face, the prop will require a taper of 11 inches in length, leaving the thin point 3 inches in diameter. A prop so treated will probably sustain a dead weight of about 16 tons before any appreciable impression is made on the tapered end. When withdrawn, the prop so treated will be found erect and sound, whilst an ordinary prop would have been broken. After the withdrawal of the prop, and finding that the “burring” has advanced, say, 4 to 5 inches along the taper, it can be re-set in the same stall on a foot-lid, and the “burring” will proceed again on the same principle. In fact, it follows that so long as a weak point is made at the end of the prop, and rendered relatively weaker than the other portion, it may be re-set in suitable places as long as there is length to set. Finally, when too short for use as a prop, it can be cut up for lids or sleepers. At one large colliery, in which the tapered props have been wholly

* *Transactions of the Institution of Mining Engineers*, vol. xviii. pp. 120-127.

† *Transactions of the Manchester Geological Society*, vol. xxvi. pp. 330-360.

‡ *Transactions of the Institution of Mining Engineers*, December 1899.

in use for some months, the consumption of props has been reduced fully 25 per cent. Bars or stretchers have both ends treated similarly to the props.

H. W. Halbaum * discusses accidents from falls of roof and sides, especially in view of the systems obtaining in the North of England and the Midlands of making the deputies or the men themselves responsible for the timbering.

H. W. Halbaum † also discusses some of the difficulties that occur in timbering, and especially deals with loose pieces of roof which cannot always be foreseen or guarded against. A more efficient system of roof examination is greatly needed, and under the present condition of affairs is of more importance than any systematic system of timbering.

G. Johnson ‡ gives a number of methods of calculating sizes and prices of timber.

E. G. Vecqueray § describes the Nodon-Bretonneau process of preserving and seasoning timber by first drying it and then making it one pole in an aqueous electrolytic bath of boro-resinate of sodium and passing a current of 110 volts.

Explosives and Blasting.—A memorandum with regard to the special testing of explosives for use in coal mines has been issued by the Home Office authorities under date October 18, 1899, and prescribes more stringent tests so as to indicate the safer explosives, which will be placed in a special list.

W. J. Orsman || gives some statistics of the explosions of firedamp and coal dust caused by explosives. He also condemns ¶ the permitted gunpowder explosives, and discusses the position of the detonator when several cartridges are placed in one hole.

The arrangement and size of bore-holes and the weight of the charges to be used are discussed.**

D. M. D. Stuart †† gives some results of the use of "bulldog" blasting powder, which contains 85 per cent. of saltpetre, 1 of sulphur, and 14 of charcoal. It is one of the permitted explosives.

Some experiments have been made on the safety of dynamite maga-

* *Colliery Guardian*, vol. lxxviii. pp. 926-927.

† *Ibid.*, vol. lxxviii. pp. 1161, 1210.

‡ *Ibid.*, p. 1067.

§ *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 427-431.

|| *Ibid.*, vol. xvii. pp. 373-387.

¶ *Transactions of the Manchester Geological Society*, vol. xxvi. pp. 229-232.

** *Allgemeine Bergmännische Zeitschrift*, November 1899, pp. 1-4.

†† *Colliery Guardian*, vol. lxxix. pp. 126-127.

zines at Blanzv with charges of about half a ton, and L. Aguilion * reports on the use of safety explosives in fiery mines.

The means used for blasting with high explosives are described and discussed by H. Bonser.†

C. H. Smith ‡ describes the apparatus and precautions employed for blasting by electricity.

Methods of Working Coal.—The working of coal mines under sea and under the Permian feeder of water in Durham is described by T. Bell,§ the extent of the workings at various collieries and the precautions taken being discussed.

A new method for working deep coal beds is described by H. M. Chance.|| In it the main haulage road and return airway are driven as narrow as possible, and then two broader roads are opened up on each side by working them back as stalls, so that there are six roads ultimately serving for ventilation and haulage if requisite.

J. B. Davis¶ describes the methods of removing the pillars in the Pennsylvania anthracite mines after the stalls have been filled with culm water-borne from the surface. The author also gives ** fuller particulars of the process and further photographs, and includes some tests to show the weight that the packed culm will withstand. A general review of the methods of flushing culm has also appeared.††

C. R. Claghorn ‡‡ describes the present and proposed methods of operating Vinton No. 3 Colliery, Vintondale, Pennsylvania, which was being developed in an isolated field of coal, under a large hill, the seam outcropping completely around the base, being about 8000 feet long and 3000 feet wide. The main rise of the coal-seam was 7 per cent. in the direction of the longer axis of the field. The seam averaged 4 feet in thickness. Roads are driven from the lower side through the long axis, and cross-roads driven off it to the outcrop every 300 feet, and the panels thus formed are worked back to the central main road by longwall.

* *Annales des Mines*, vol. xvi. pp. 551-573.

† *Iron and Coal Trades Review*, vol. ix. pp. 165-166.

‡ Paper read before the Technical and Engineering Society of Golden, Colorado, through *Industries and Iron*, vol. xxviii. p. 4.

§ *Transactions of the Manchester Geological Society*, vol. xxvi. pp. 366-399.

|| *Transactions of the American Institute of Mining Engineers*, February 1900.

¶ *Mines and Minerals*, vol. xx. pp. 289-290; see also *Journal of the Iron and Steel Institute*, 1898, No. I. p. 418.

** *Journal of the Franklin Institute*, vol. cxlix. pp. 271-282.

†† *Colliery Guardian*, vol. lxxix. p. 418.

‡‡ *Transactions of the Institution of Mining Engineers*, vol. xviii. pp. 351-361.

J. T. Beard * discusses the different systems in vogue of driving the workings face on, end on, and at an angle with the cleat. The sizes of the stalls and other kindred matter is also dealt with.

The working of thin seams in the Dortmund coalfield is described.†

Tübben ‡ discusses the use of liquid air for cooling hot working places in collieries.

A new method of working at the Grand'combe Colliery in the Le Gard Department, France, is described by Destival.§ The seam dips about 1 in 66, and the working face is placed at such an angle that the empty tubs brought in on one side run along it and away from the other end of the stall through a gob road.

Berne || describes the plant in use at the St. Etienne Collieries for utilising the power generated by lowering material for storage purposes underground to drive air-compressors. About 600 tons are sent to a depth of over 300 yards in an eight-hour shift, and the compressors give about 60,000 cubic feet of air at 79 lbs. pressure.

The coal famine in Germany has been so severe that it has led to greater efforts than ever before to open up new coal-seams.¶ Much attention has been devoted to this in the Ruhr district and its continuations. Numerous bore-holes are being put down in search of coal, and that, too, far across the Lippe. At depths of some 650 to 750 yards coal has been found in this district. Near Dorston a seam has recently been struck at a depth of 2137 feet; its thickness was about 4 feet 9 inches. The farther north these explorations are made in this district, the more difficult do they become, owing to the enormous depths at which the coal-seams must be sought.

The question as to how far it is possible to diminish the losses of coal that now take place in coal-mines is next considered. Safety pillars have absorbed enormous quantities of coal, and it has become a serious question whether it is not possible to modify the system of working adopted in such a manner as to enable the loss to be avoided. How great it is may be seen from the fact that the coal contained in these safety pillars in Westphalian collieries alone is estimated at about 28,600,000 tons. It is not at all improbable, as Festenberg remarks, that in the whole of these various districts in question the total loss in

* *Mines and Minerals*, vol. xx. pp. 365-367.

† *Glückauf*, vol. xxxv. pp. 997-999.

‡ *Ibid.*, pp. 577-578.

§ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 225-232.

|| *Ibid.*, 1899, pp. 270-277.

¶ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. p. 111.

this way may amount to 100,000,000 tons. If it should prove possible to combine the various colliery undertakings, great improvements would be achieved, and it is probable that some such scheme may before long be perfected in the Ruhr coalfield. Other points are also briefly dealt with.

H. Winklehner * describes the methods of mining adopted in the brown coal-seams of the Annathal Colliery at Gran, in Hungary, one of the oldest collieries in the kingdom. The mine was started in 1805, and four seams are worked. The uppermost seam is of Oligocene age, whilst the three seams 80 to 100 yards below it are of Eocene age. The stratification of the latter seams is much disturbed, and the inclination varies from 12° to 80°. The brown coal is of good quality, containing 53·82 per cent. of fixed carbon; its calorific power is 4800 to 4900. The coal is liable to spontaneous combustion. When it is placed in heaps at the surface over 6 feet in height, in four or six weeks the lower portions are found to be in a state of ignition. This tendency to spontaneous ignition has necessitated the adoption of special methods of working. The preparation of fire-dams is also a matter of importance. Since the introduction of accumulator electric lamps and of breathing apparatus, fire-dams, which formerly required 120 to 260 shifts, can now be made by six men in twenty-four hours.

F. E. Suess † discusses the existence of phenomena connected with underground springs in the Teplitz district and eruptions of water and quicksand in the brown coal mines. The same subject is dealt with by L. de Launay, ‡ and the method of working brown coal in this district is described in detail in the *Colliery Guardian*.§

Mine Drainage.—The various methods of pumping and of transmitting power to and driving pumps are considered and compared. || The methods of winding water and of installing underground pumps driven by gas-engines or by underground boilers are touched upon.

W. H. Booth ¶ gives a general account of the electric pumping plant in the South Staffordshire district.

Illustrations are given ** of the pump designed by H. Ashley for

* *Allgemeine Bergmännische Zeitschrift*, January 15, 1900, pp. 1-4.

† *Jahrbuch der k.k. Geologischen Reichsanstalt*, vol. xlviii. pp. 425-516.

‡ *Annales des Mines*, vol. xvi. pp. 103-136.

§ Vol. lxxviii. pp. 540, 602, 635, 683, 732.

|| *Engineering and Mining Journal*, vol. lxxviii. p. 552.

¶ *Mines and Minerals*, vol. xx. pp. 134-135.

** *Iron and Coal Trades Review*, vol. lx. pp. 216-217.

sinking and other purposes. Its special feature consists in the arrangement of the valves, which are placed in the walls of the bucket or plunger, and replace the ordinary bottom clack.

Illustrations have appeared * of the Ross-Browne baling-tank for winding water. It is one of the closed type, filled by exhausting the air.

The Tomson water-barrel, used in sinking the shaft at Sprockhövel Colliery, in the Witten mining district of Germany, where feeders of water of unexpected size were encountered, is illustrated.†

C. Wood ‡ describes the Pohle air-lift system of raising water.

Von Sobbe § gives an illustrated description of the Rittinger pumps at the Ibbenbüren Colliery, Westphalia.

Winding and pumping installations at the Witkowitz Colliery, Dombrau, are described by A. Fillunger, || with the aid of several illustrations of the plant.

S. Steuer ¶ describes an underground pumping-engine erected at a colliery at Ettes, near Salgo-Tarjan, Hungary, to raise 330 gallons per minute on the average to a height of 220 yards. The dimensions of the engine are: Diameter of high-pressure cylinder, 19·7 inches; low-pressure cylinder, 31·5 inches; diameter of the plunger of the force pump, 10·2 inches; common throw, 23·6 inches; diameter of piston of the air and accessory pump, 21·6 inches; throw of same, 11·8 inches; speed per minute, 50 to 67 revolutions; boiler pressure, 95 to 100 lbs. Corliss and Riedler valves are fitted.

H. Domage ** describes the driving of the great adit level from Gardanne to the sea at the Bouches-du-Rhône Colliery. It is expected that the adit will be completed in 1902.

The Ventilation of Collieries.—J. T. Beard †† discusses the design and use of centrifugal ventilators largely from a mathematical point of view, based on certain formulæ proposed some years ago by himself. The designs for several fans running at different speeds are calculated.

* *Colliery Guardian*, vol. lxxviii. p. 938.

† *Iron and Coal Trades Review*, vol. lx. p. 253.

‡ *Cleveland Institution of Engineers, Proceedings*, 1900, pp. 12-28.

§ *Zeitschrift für das Berg-, Hütten-, und Salinenwesen im preussischen Staate*, vol. xlvii. pp. 334-374.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 473-475, 487-489.

¶ *Ibid.*, vol. xlvii. pp. 341-344.

** *Bulletin de la Société Scientifique et Industrielle de Marseille*, vol. xxvi. pp. 173-193; *Annales des Mines*, vol. xvi. pp. 307-435, 457-498.

†† *Mines and Minerals*, vol. xx. pp. 54-56, 104-105.

R. C. Carpenter * gives some further details of his tests of blowing fans, with comments on the use of the Pitot tube and the anemometer.

C. H. Innes † describes some forms of screw fans, with some tests.

The results of a test of a Capell fan, 16 by 6 feet, made at the Eureka Mine, Windber, Pennsylvania, are given. ‡

Löwenstein § has published the results of a comparison of the working of the electrically driven Capell and Mortier fans at the Bonifacius Colliery, near Kray. It was found that, in ordinary circumstances, the Capell fan gave the same amount of air as the Mortier fan, but used somewhat less power.

Laponche || gives the results of some tests of Rateau fans, one 4 feet 10 inches in diameter, at the Mines du Cros, and one 13 feet in diameter at the Monopol Colliery, near Dortmund.

P. Petit ¶ describes the automatic appliances for continuously recording the fan speed and pressure devised by Villiers at the St. Etienne Collieries.

Fire-Damp Explosions.—E. Harzé ** has dealt at some length with the relationship between fire-damp and seismic disturbances, but fails to trace any direct connection.

Lebreton †† discusses the apparent cause of error in fire-damp determination by the limits of inflammability, and finds that it is due to the angle at which the test-tube is held. The limit appears to be constant at each inclination.

The ignition of fire-damp and coal-dust by means of electricity is discussed by S. F. Walker ‡‡ in view of the experiments made by Heise and Theim.

T. H. Mottram §§ summarises and discusses the statistics of explosions of fire-damp and coal-dust in the West of Scotland.

* Paper read before the American Society of Heating and Ventilating Engineers; *Engineering News*, vol. xliii. pp. 101-103.

† Paper read before the North-East Coast Institution of Engineers and Shipbuilders, December 14, 1899.

‡ *Mines and Minerals*, vol. xx. p. 113.

§ *Glückauf*, vol. xxxv. pp. 886-892.

|| *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1898, pp. 217-221.

¶ *Ibid.*, 1899, pp. 169-172.

** *Annales des Mines de Belgique*, vol. v. No. 1.

†† *Annales des Mines*, vol. xvi. pp. 95-102.

‡‡ *Colliery Guardian*, vol. lxxix. pp. 64, 109, 161.

§§ *Transactions of the Institution of Mining Engineers*, vol. xviii. pp. 186-193.

J. Mayer * describes an explosion of fire-damp which took place at the Heinrich Colliery in Moravian Ostrau, and also some experiments with safety-lamps which were subsequently made with a view to ascertain exactly how the explosion originated. The explosion was not a severe one, and caused no deaths, and would not have been deserving of notice were it not for the difficulty found in explaining how it originated. The author thinks that the gas-blower was the real cause of the accident. He enumerates the various ways in which the flame of a safety-lamp may strike through the gauze, and describes experiments that were made in order to ascertain which of these it was that caused the explosion under consideration. He based his experiments on the assumption that the explosion was due to one of the following causes:—(1) The lamp, the fall of which caused the explosion, struck against something in its fall, this fall taking place in an explosive mixture, the lamp being already filled with gas; (2) that the red-hot wire gauze may have set fire to the clothing of the person carrying it, in an attempt to put it out; (3) to the Wolff percussion igniting arrangements having caused the flame to strike through the gauze; or (4) to the flame having struck through the lamp owing to this having been brought in contact with gas currents or blowers.

With each of these he deals in detail, illustrations being given of the system of experimenting employed.

That the shock of a lamp falling or knocking against something is of influence is evident, but this influence is not so marked as was considered probable. As long as the velocity of the air current was not considerable, the flame only very rarely passed out of the lamp in this way, and that too usually not at the moment when the lamp fell, but when it was suddenly lifted again. When the velocity of the air current reached 31 feet 9 inches and the percentage of gas present 7·15, the flame passed out of the lamp in every instance in 25 seconds, and that without any movement of the lamp. These results are not quite in accord with those obtained by the Austrian Fire-Damp Commission, who found that, using a similar lamp to that employed by the author, the result referred to was only reached when the air current attained a velocity of 36 feet 1 inch. Sometimes the authors attribute such passages of the flame through the gauze to the fact that the meshes are not all of even size, even though the gauze may have the right

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 53-56, 68-72, 83-86, 100-103, 109-111, with sheet of illustrations.

total number of meshes to the square inch. It is quite possible, the author shows, that the workmen's clothing may be brought to ignition by the lamp, and thus lead to gas explosions, and danger results when it is attempted to put out a lamp with red-hot gauze in the manner described by the workman who caused the accident.

Dealing next with the question as to whether the explosion might have been caused by the Wolff igniter used, the author describes experiments made by him in this direction. The author refers to experiments by Spoth, who showed that explosions due to this cause took place regularly when the velocity of the air current reached 28 feet 10 inches and the percentage of fire-damp was 8.5. The author shows that in the case under consideration the velocity was less than that found requisite by Spoth to produce an explosion, and the results are given of the experiments he made. In no single case did an explosion outside the lamp result, even when the velocity exceeded 32 feet and the percentage of fire-damp amounted to 9. The author, therefore, considers that the re-lighting in this way of the Wolff lamp with two gauzes is free from danger, or, at the very least, less dangerous than subjecting the lamp to very rapid air currents and high fire-damp percentages. Only when the gauze was red-hot and the lamp alight did explosions result with this lighting arrangement (it consists of a band carrying a series of caps which can be exploded). In such cases, even in air currents of relatively low velocity, and in the presence of relatively low percentages of fire-damp, explosions frequently occurred.

In the collieries under the author's control, 6389 Wolff safety-lamps are employed. Of these, 1353 are provided with friction igniters, and 2335 with the old percussion igniters. It was one of these latter which was the cause of the explosion. The author discusses the probable causes which led to such very different results being obtained by Spoth and by himself, and shows that the lamps and lighting arrangements employed in the two cases were different. The author thinks that a gas-blower was the probable cause of the explosion, and experiments were made by him with a view to ascertain the degree of probability for this assumption. These he describes, and shows that they prove that it is very dangerous for a blower to come in contact with a lighted lamp, even with low velocities of air current. The general conclusion the author has arrived at is that the explosion was, in fact, due to such a blower acting directly on the lamp. Fortunately such cases must be rare. Still the greatest caution should be taken in testing for gas with the safety-lamp when a blower has to be approached.

A list is published, with short explanatory statements in each case, of the more important accidents in mines that have occurred in the last four years. Over 130 cases are referred to.*

In an elaborate mathematical paper J. Beaupain† applies the theory of probabilities to the frequency of outbursts of fire-damp.

Petit‡ discusses the influence of earth tremors on the occurrence of fire-damp, with special reference to Chesneau's experiments at the Anzin Collieries.

The Extinction of Fires in Mines.—A recently published book on fires in mines, by R. Lamprecht,§ is divided into seven sections, the first treating of the origin of underground fires, the second of preventive measures, and the third of indications of the presence or breaking out of a fire. The fourth describes appliances for enabling miners to enter galleries or other places full of irrespirable gases. The fifth is devoted to various appliances and methods for dealing with underground fires. The sixth treats of rescue stations for preserving life. The seventh and last refers to fires in stock coal heaps (spontaneous combustion) and in coal cargoes.

W. H. Chambers|| gives an illustrated description of a number of gob fires and the methods adopted for coping with them. They are always to be feared until the goaf is completely settled, and uniform working is therefore requisite.

H. Stoker,¶ in a recently delivered lecture, deals with the prevention and extinction of gob fires. Increased ventilation, taking out more of the coal, and cooling the air, aid in the prevention and in the extinction. After dealing with the older methods, the use of freezing mixtures, such as calcium chloride and ice or cooled brine, is described.

J. Ashworth** deals with the effect of moisture and cooling on gob fires.

The discussion on the origin of gob fires is continued by H. W. Halbaum.††

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 41-44.

† *Annales des Mines de Belgique*, vol. v. pp. 1-28.

‡ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1900, p. 6.

§ *Die Grubenbrandgewältigung*, pp. 144, with 7 plates. Leipzig.

|| *Transactions of the Institution of Mining Engineers*, vol. xviii. pp. 154-167.

¶ *Colliery Guardian*, vol. lxxix. p. 180.

** *Ibid.*, p. 363.

†† *Ibid.*, p. 545.

A. Dory * describes the means of dealing with the underground fires at a colliery in Arnao, Asturias.

A report made to the Secretary of the United States Navy deals with the spontaneous ignition of coal. Extensive reference is made to the Report of the Royal Commissioners of Great Britain on fires in coal cargoes, published in 1876, and the paper of Prof. Vivian B. Lewes, of the Royal Naval College, Greenwich, published in 1891, and the conclusions there set forth are, in the main, adopted. Anthracite is, on the whole, distinctly inferior to bituminous coal for naval use, except in the freedom from spontaneous ignition, and the comparative rarity of this phenomenon on American ships shows that this advantage does not outweigh the numerous and important disadvantages.†

Some notes on the storage of gas-coal, especially in view of the problem of spontaneous combustion, are given by Irving.‡

Sarter§ describes the mine gallery constructed for experiments with explosions caused by coal-dust at the Maria Colliery, near Höngen, in the Aix-la-Chapelle district.

R. Harle|| describes an automatic arrangement for damping the coal in the tubs as they leave the face or at any other point, in order to prevent the accumulation of dust. The tub as it passes along the rails opens a valve and allows an overhead spray pipe to play on the coal.

The Lighting of Collieries.—Kreutz¶ deals with the question of the breaking of the glass in safety-lamps, and gives some statistics.

Balzer ** describes some tests of the Wolff, Hübner, and Broncek safety-lamps fitted with igniting appliances.

H. Baugniet †† describes a magnetic lock, a pneumatic lock, and the Bomal lead rivet lock used at the Grand-Hornu Colliery in Belgium.

Dehnke describes the magnetic lock for safety-lamps devised by W. Debus. ‡‡

* Paper read before the Société des Ingénieurs des Mines du Hainaut.

† *Industries and Iron*, vol. xxvii. pp. 430-431.

‡ Paper read before the Southern Association of Gas Managers; *Iron and Coal Trades Review*, vol. lx. p. 455.

§ *Glückauf*, vol. xxxv. pp. 561-564.

|| *Transactions of the Institution of Mining Engineers*, vol. xviii. pp. 113-119.

¶ *Colliery Guardian*, vol. lxxix. p. 369.

** *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 323-333.

†† Paper read before the Société des Ingénieurs des Mines du Hainaut.

‡‡ *Glückauf*, vol. xxxv. pp. 698-699.

J. Goffin describes the improved Sussmann lamp at the Strépy-Bracquenies Collieries.*

According to Kuhn,† some trials have lately been made in the Neu-Diepenbrock III. mine, owned by the Selbeck Mining Company, of a miner's lamp fed with acetylene, designed by the Velo-Company of Dresden-Lobtau; and the results were satisfactory, although a few modifications in the direction of greater strength are recommended.

K. Baumgartner ‡ describes a form of acetylene lamp for miners' use.

Rescue Appliances for Collieries.—The organisation of rescue work in mines, and the appliances used, are discussed by H. Rössner.§

H. Deans || describes the pneumatophor rescue appliance for use in mines with the aid of illustrations.

New regulations for the protection of the health of miners in the Dortmund district have been drawn up. The chief provisions are as follows:—At every shaft a dressing-room must be provided. At every colliery shower-baths must be available. Water from the shaft sump may not be used, and the use of a common plunge-bath is forbidden. At every mine an adequate number of latrines must be provided above and below ground. In underground workings and engine-rooms the workmen must not be employed for more than six hours a day if the temperature exceeds 84° F. At every shaft there must be at least two persons qualified to render first aid to the injured. A supply of surgical appliances must be in readiness, and one stretcher must be provided for every 100 miners employed.

History of Coal-Mining.—A biography of the late James Nixon gives particulars of his connection with the history of the steam-coal trade in Wales.¶

The translation of a Norman-French charter or lease dated 1325, and relating to coal worked at Birtley, in Durham, is given by R. L. Galloway.**

* *Revue Universelle des Mines*, vol. xlvii. pp. 257-263.

† *Colliery Guardian*, vol. lxxviii. p. 1071.

‡ *Allgemeine Bergmännische Zeitschrift*, February 8, 1900, pp. 6-8.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 519-522, 531-534.

|| *Transactions of the Manchester Geological Society*, vol. xxvi. pp. 223-228.

¶ "The Life of John Nixon, Pioneer of the Steam-Coal Trade in South Wales." By James Edmund Vincent. With a Portrait. London: John Murray, Albemarle Street. 1900.

** *Colliery Guardian*, vol. lxxviii. p. 1067.

J. B. Jones * discusses the coal dues levied at Dover.

Mine-Surveying.—E. H. Liveing deals with the connection of underground surveys with the surface by the transit method.†

F. Seeland ‡ gives the results of observations of magnetic declination at Klagenfurt. O. Brathuhn § describes the use of the Langer hanging-compass in the presence of iron. K. Benndorf || discusses the use of the Saxon mine-surveying appliances.

Subsidence Caused by Mining.—In the resumed discussion ¶ on J. Dickinson's paper on subsidence caused by colliery workings, a number of varied opinions are expressed, and A. Mort gives a running commentary on the literature concerning the subject, giving a number of references.

Menzel ** discusses the relation between the thickness of the seams worked, and the amount of subsidence at the surface in the Zwickau coalfield.

T. Andrée †† considers the question of the protection of the surface in mining operations. He deals especially with the Austrian regulations relating to this matter.

The Economics of Coal-Mining.—A. Smith †† discusses the rating of coal-mines, and the same subject is dealt with by G. Humphreys-Davis. §§

The redemption of capital expenditure upon collieries and the valuation of mining capital is discussed by G. Johnson. ||

The application of different methods of depreciation to mining property is discussed by the same author. ¶¶

Collieries in Great Britain.—Detailed descriptions have been published in the *Colliery Guardian* of a number of British collieries.

* *Iron and Coal Trades Review*, vol. lx. p. 162.

† *Transactions of the Institution of Mining Engineers*, vol. xviii. pp. 65-71.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, p. 511, 535, 586, 639.

§ *Ibid.*, 1899, p. 537.

|| *Ibid.*, 1899, p. 581.

¶ *Transactions of the Manchester Geological Society*, vol. xxvi. pp. 50-81.

** *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1899, pp. 147-161.

†† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 525-531.

‡‡ *Transactions of the Institution of Mining Engineers*, vol. xviii. pp. 171-177.

§§ *Ibid.*, pp. 228-250.

||| *Colliery Guardian*, vol. lxxix. pp. 66-68.

¶¶ *Ibid.*, vol. lxxviii. p. 877.

The list includes the following in the Durham coalfield :—Charlaw, Sacriston (vol. lxxviii. p. 830), and Kimblesworth (p. 875), Derwent (p. 925), Wingate Grange (p. 974), Ushaw Moor, Esh, and Waterhouses (p. 1020), Esh (p. 1068), Randolph (p. 1116), Hebburn (p. 1212), Ryhope (vol. lxxix. p. 111), Usworth (p. 303), South Hetton and Murton (p. 450), Houghton (p. 543), Wearmouth (p. 594), Beamish (p. 688).

The collieries in the Northumberland coalfield described are :—Linton (vol. lxxix. p. 63), Walker (p. 160), Backworth (p. 208), Behside (p. 270), East Holywell (p. 350), Newburgh (p. 400), Choppington (p. 498).

A list has been published* of the anthracite collieries in South Wales, with their situation and the number of hands employed by each. An account is also given of Deep Navigation, Treharris, Glamorgan,† and the Chisnall Hall Collieries, Coppull, are described.‡

The Hamilton Place Colliery in Lanarkshire is described by J. S. Dixon.§

Colonial Collieries.—H. F. Bulman|| describes the Blackball Colliery in New Zealand, where a wire ropeway is used for carrying the output to the railway. Other colonial collieries are described by the same author.

Some photographs of the works of the Acadia Coal Company, Pictou County, Nova Scotia, have been published.¶ Operations are conducted at three points. At Acadia Colliery the seam is 10 feet thick and dips 27 degrees. The incline is 4200 feet long, the extreme vertical depth being 1800 feet. The seam is worked in lifts of 300 feet longwall with timber packs 5 feet square. At Albion Colliery the main seam is 38 feet thick; the deep seam, 148 feet lower, is 22 feet thick. There has been a fire in the old rise workings for twenty-five years. At Vale Colliery the seam is 6 feet in thickness.

The Natal Navigation Collieries are described.**.

A description has appeared of the Onspoed Colliery †† in the Middel-

* *Iron and Coal Trades Review*, vol. lix. p. 939.

† *Ibid.*, vol. lx. p. 117.

‡ *Ibid.*, vol. lx. p. 208.

§ *Transactions of the Institution of Mining Engineers*, vol. xviii. pp. 55-57.

|| *Colliery Guardian*, vol. lxxviii. p. 746.

¶ *Canadian Mining Review*, vol. xix. pp. 38-41.

** *Iron and Coal Trades Review*, vol. lix. p. 757.

†† *Ibid.*, vol. lix. pp. 1136-1137.

burg district of the Transvaal and of the Vereeniging* Collieries on the Vaal river.

Coal-Mining in India.—In a collected edition of Rudyard Kipling's works † which is being published in this country, is included one of his early sketches describing a visit to the Giridih coalfields. It is a picturesque, though perhaps not very technical account of the surface and underground workings and surroundings, with much about difficulties of dealing with the labourers employed.

American Collieries.—A. Dinsmore ‡ describes several of the collieries in the north-eastern district of Illinois, and the Spring Valley Collieries in the same State are described by J. A. Ede.§ A. Lakes || deals with the Grand River coalfield of Colorado, and with prospecting for coal in that State. A. Roy ¶ gives an account of the Coalton coalfield in Kentucky. The coalfields and collieries of Indiana are discussed by G. H. Ashley.**

B. Harding †† describes the Eureka Collieries in Somerset County, Pennsylvania.

E. H. Coxe †† describes the Kelly's Creek Collieries in West Virginia.

Collieries in Spain.—A. Dory §§ describes the coal-bearing formation of the Asturias and the undersea workings at Arnao on the Bay of Biscay. The workings are packed with gob material lowered from the surface. The coal is liable to spontaneous combustion, and the method of dealing with underground fires is described.

Coal-Mining in Servia.—According to E. Heguer and J. François, ||| coal-mining in Servia is still in a very primitive condition, although there are coal deposits in abundance in that country. The coal mined is chiefly of Tertiary age. The principal colliery now in operation is near Alexinat. It has a shaft 170 feet in depth. The output comprises 30 per cent. of large coal, 30 per cent. of cobbles,

* *Iron and Coal Trades Review*, vol. lx. pp. 23-24.

† *Writings in Prose and Verse*, vol. xvii. pp. 195-222. Macmillan & Co., 1900.

‡ *Mines and Minerals*, vol. xx. pp. 106-108.

§ *Ibid.*, pp. 150-153.

|| *Ibid.*, pp. 110-111, 148-149.

¶ *Ibid.*, p. 123.

** *Ibid.*, pp. 202-205, 246-248.

†† *Engineering and Mining Journal*, vol. lxi. pp. 197, 230.

‡‡ *Ibid.*, vol. lxi. p. 166.

§§ From a communication to the Société des Ingénieurs des Mines du Hainaut.

||| *Mining Journal*, vol. lxi. p. 1423.

30 per cent. of nuts, and 10 per cent. of dust. The colliers receive per cubic yard 1s. 2½d. for undercutting, 9½d. for getting, and 7½d. for the coal obtained. Haulage and winding cost 7½d. per cubic yard, and timbering 2½d. per ton. The total cost thus amounts to about 3s. 6d. a ton, whilst the selling price averages 5s.

IX.—COAL-WASHING.

Coal Screening and Washing.—Illustrations and sections have recently appeared * of the coal-washing plant at the Cadeby Colliery near Doncaster. The capacity is 1000 tons in ten hours. A mixture of hard and soft coal containing much friable shaley coal is treated. The coal is screened in Humboldt's screen with three concentric surfaces making four sizes, of which the smallest is further screened in a second machine to take out the dust. This latter is mixed with the sludge and used for boiler-firing. The washing jigs are fitted with differential lever gear to give a quick down-stroke and slow up-stroke.

Important improvements † have recently been introduced in the Puertollano Collieries. Among others, the installations comprise a briquette-making plant with a capacity of 50,000 tons, an increase of the screening plant, a washing plant for the treatment of small coal, an underground electric haulage plant, and a central electric power station.

Illustrations have appeared ‡ of a vibratory conveyor and screen consisting of troughs which may be built up to 100 feet in length, supported above or below by rocker arms every ten feet. A vibratory motion is given by crank shafts.

Frank Pardee has designed an adjustable spiral separator for anthracite.§ It consists of a continuous spiral round a central support. The coal and slate from the screens enters the spiral at the top, having been divided into two streams in broken and egg sizes by a special feeder. As the material descends the coal slides over the edges, falling against a flange by which it is deflected into the channel, round which it follows to the bottom of the spiral, while the heavier

* *Iron and Coal Trades Review*, vol. lx. p. 549, with plate; *Colliery Guardian*, vol. lxxix. pp. 546-547.

† *Revista Minera*, vol. li. pp. 33-34.

‡ *Iron and Coal Trades Review*, vol. lxx. p. 858.

§ *Anthracite Coal Operators' Association Letter*, 1900, pp. 48-49.

slate follows down the separating plates to the bottom. There the coal enters one shoot, the slate another, and the mixed material on the outside of the separating rounds a third. The capacity of the separator is 100 tons egg-sized coal in ten hours. The arrangement of spirals requires about $9\frac{1}{2}$ feet. Excellent results have been obtained with this separator at the Cranberry mines.

The surface works at the Bruay Colliery are described in great detail by M. Sohm.* The paper is illustrated by eight working drawings.

Handling Coal.—The Henderson cableways and cable conveyors are illustrated as applied to handling coal and to quarries.†

A. J. S. B. Little ‡ gives a large number of illustrations of various forms of conveyors adapted to many kinds of work. Amongst the materials dealt with are coal, coke, ore, steel billets, rails, &c. &c.

Illustrations have appeared § of the Wall apparatus for handling coal at Nanaimo, British Columbia.

C. Ingre ‖ discusses the use and construction of automatic coal-weighing and recording machines, especially those used for handling coal when loading.

The various methods of emptying coal-boats are described by J. G. Marshall.¶ Hand labour and different forms of conveyors and grabs are dealt with. The Hone grab referred to is also illustrated elsewhere.**

S. Miller †† reviews the methods adopted for coaling vessels at sea, and describes his wire ropeway system for use between the collier and the vessel.

An illustration has also appeared ‡‡ of the Brown conveyor plant at the Navy Yard, New London, Connecticut, for loading vessels with coal.

* *Bulletin Technologique*, 1900, pp. 195-233.

† *Iron and Coal Trades Review*, vol. lix. pp. 856-858.

‡ *Engineering Magazine*, vol. xviii. pp. 501-522.

§ *Colliery Guardian*, vol. lxxviii. p. 1037.

‖ Paper read before the Cleveland Institution of Engineers, April 1900.

¶ Paper read before the Association of Mechanical Engineers, Birmingham, March 3, 1900.

** *Iron and Coal Trades Review*, vol. lx. p. 25.

†† Paper read before the Society of Naval Architects and Marine Engineers, November 1899; *Iron Age*, November 23, 1899, p. 8; *Engineering Magazine*, vol. xviii. pp. 710-721.

‡‡ *Iron Age*, January 18, 1900, pp. 1-2.

PRODUCTION OF PIG IRON.

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I.—BLAST-FURNACE PRACTICE.

Modern Blast - Furnace Plant.—T. B. Rogerson * compares American and British blast-furnace practice, giving a short account of the practice in Scotland and in the United States. The large makes of the American furnaces are entirely owing to the very much greater pressure of blast used, thereby bringing the charge down very rapidly and causing quick smelting, even with the large proportion of small rich ores, which is about 40 per cent. of the burden, and as fine as sand. The great pressure does not allow the material to rest on the walls of the furnace, which causes scaffolds on the bosh and much trouble and annoyance to the furnace manager, who at once blames small ores and bad fuel for the troubles. Having got the furnace to drive regularly at from 2000 to 5000 tons per week, the difficulty then presents itself of how the furnace is to be filled regularly. This had to be done by adopting machinery in place of men and shovels. In this particular work there is very little more machinery to keep up than in Scotland, but, of course, the arrangement of bunkers, &c., is very much more costly. The disposal of a very large quantity of iron could not possibly be done in sandbeds at the furnace, and must be carried away by a ladle, so that the casting-machine for making pigs is the only thing that can deal with the

* *Journal of the West of Scotland Iron and Steel Institute*, vol. vii. pp. 167-171.

molten metal. The same remarks apply to the slag, and the whole arrangement has been caused by necessity.

The Youngstown Blast-Furnaces.—Numerous illustrations and plans have appeared* of the plant for two new blast-furnaces at Youngstown, Ohio. The loaded trucks run by gravity to a lift which raises them and tips their contents into four trucks mounted on two transfer trucks, which take them to bridges spanning the stockyard or bins. Each furnace has one limestone bin, one coke bin, and nine ore bins, each holding 500 tons, and having six bottom-delivering shoots on either side. The furnace skip holds 15,000 lbs. of ore, 8000 lbs. of limestone, or 4000 lbs. of coke. It is lifted by electrically-driven rope-gear, and discharges into a hopper on the furnace top. A small bell at the bottom of the hopper delivers the charge into the main bell, which will hold 30,000 lbs. in the gas-tight hopper. The bells are worked by counterbalanced levers and oscillating cylinders.

The furnace-stacks proper are $106\frac{1}{2}$ feet high, and have a 15-foot crucible and a 23-foot bosh. They are 17 feet in diameter at the stock-line, and have a 12-foot bell. The hearth is equipped with eleven rows of Scott copper bosh-plates and two upper rows of cast-iron plates with coils. There are sixteen 6-inch bronze tuyeres. The mantle-plate is of cast-steel, and the eight columns have a height of 27 feet 9 inches. Each furnace is provided with two 5-foot explosion doors, a $2\frac{1}{2}$ -foot bleeder, and a bifurcated down-comer 7 feet in diameter in the clear. The dust-catcher has a diameter of 30 feet, and the gas is delivered through two Steese horizontal gas-washers, 10 feet $9\frac{3}{4}$ inches inside diameter. Each furnace is flanked by four two-pass Cowper-Kennedy-Roberts hot-blast stoves, 118 feet high and 21 feet in diameter. They are provided with side combustion chamber, and are built of the Roberts brick. A Heyl and Patterson pig-iron casting-machine, with a capacity of 2000 tons per day, is being erected. The blowing-engines are of the vertical, cross-compound, condensing type, with steam-cylinders 54 inches and 102 inches in diameter, with 60-inch stroke, and two air-cylinders 108 inches in diameter, 60-inch stroke. The ladles, which are also illustrated, have a rolling motion on their trolleys.

The account of these blast-furnaces appears, with some annotations by F. W. Lürmann.†

* *Iron Age*, December 21, 1899, pp. 1-13; *Colliery Guardian*, vol. lxxix. pp. 18-19.

† *Stahl und Eisen*, vol. xx. pp. 141-150; 14 illustrations.

Blast-Furnace Burdens.—W. Macfarlane * gives two methods of calculating the amount of limestone that should be used in the charge to combine with the silica in the ore, allowance being made for the silicon reduced into the iron. An example is given fully worked out. The author also deals generally with the question of proportioning the lime and silica in the charge, and on the influence of alumina and magnesia with the slag and iron.

Washed and Unwashed Coal in Blast-Furnaces.—C. A. Meissner † gives some notes on the comparative value and cost of Drummond coal in its washed and its raw states, and on the coke made from each variety, to show the value of washing. The comparative value of this soft coal and the coke in the blast-furnace is then discussed, and it is shown that there is very little to choose except in the matter of convenience, though it is sometimes advantageous to add some coal to improve the quality of the gas.

Damping Down Blast-Furnaces.—F. W. Lürmann ‡ refers to the condition of the Creusot blast-furnaces during a recent strike. At the time of the strike, which occurred suddenly, three blast-furnaces were making basic and one forge pig iron. After the furnaces had been damped down for a few days, the water available for the tuyeres ran short, and it was decided to allow them to remain in the furnaces, and to run the risk of having to renew them when the furnaces were again put into blast. In one of the furnaces making basic metal, air evidently penetrated, as the bell became hot, and smoke also appeared. All cracks in the vicinity of the lower portion of the furnace were then carefully stopped, and the leakage of air ceased. When it was subsequently desired to put the furnaces into blast, it was found that, in the case of three of them, bars could easily be inserted through the tuyeres; but in the fourth furnace, which was the one with which the air difficulties above referred to had been experienced, the bars met with resistance in the middle of the crucible portion of the furnace. In each case the bars became warm, but in no instance did they become red-hot. After twenty days' cessation of work, arrangements were made to heat up each pair of the hot-blast stoves attached to a blast-furnace by the aid, first, of a gas-coke fire, and then of one of coke and

* Papers read before the South Staffordshire Institute. See also *Journal of the Iron and Steel Institute*, 1892, No. I. p. 233.

† *Journal of the Mining Society of Nova Scotia*, vol. iv. pp. 66-70.

‡ *Stahl und Eisen*, vol. xix. p. 1101.

coal. After this had been done, using as large quantities of fuel as was possible for forty-eight hours, preparations were made to blow-in the blast-furnaces. All tuyeres were taken out, and were found to be in good condition, and no sign of fire was observable at the tuyere level. The subsequent blowing-in of the furnace proceeded in the usual manner, blast of a temperature of from 250° to 300° C. being first employed. As the blast temperature increased, it became possible to tap off slag regularly; but in the case of the furnace which was making forge pig iron, and in one of the others, slag had to be tapped off at a higher level, as the pig iron in the furnace had solidified. In two days' time, however, it became possible to tap off the slag from the original slag openings in each of the furnaces. The slag had then become light in colour, and the furnaces were working properly. Other details are also given.

A Blast-Furnace Accident.—Illustrations by L. Metz* of the results of a blast-furnace explosion at Rodingen are published. The furnace in question had been stopped for repairs for about ten days, and at five o'clock on the afternoon of Saturday, November 4, 1899, it was again put into blast. Slag was tapped several times, and the furnace appeared to be working in a quite normal manner. At ten o'clock an explosion of a kind occurred, though no sound was heard. The blast-furnace was broken across at the top, and, after being lifted, dropped back again on the lower armoured portion of the stack. This is well shown by the illustrations, which are taken from photographs. Two lives were lost.

Blast-Furnace Charging Apparatus.—Illustrated descriptions of numerous forms of charging apparatus for blast-furnaces have recently appeared from different sources. Amongst them are those of Stevenson, the Carnegie Company, and Kennedy.†

A section has been published of the distributing apparatus, hopper and bell, of the No. 1 furnace of the Lorain Steel Company, and also some diagrams to show the profile of the charge in the furnace.‡

The furnace-hoist devised by F. Brown§ dispenses with the employment of top-fillers, all operations being conducted by one man standing on the engine at the base of the hoist. The hoist consists of an

* *Stahl und Eisen*, vol. xx. pp. 33-34; 2 illustrations.

† *Iron and Coal Trades Review*, vol. lx. pp. 455-456.

‡ *Iron Trades Review*, October 19, 1899, pp. 16-17.

§ *Colliery Guardian*, vol. lxxviii. p. 924.

inclined iron-trussed bridge reaching from the floor of the stock-house to the top of the furnace-shell, and from thence, over the top opening of the furnace. On this bridge is laid T-rails, on which travels a skip or car, containing the charge of 2000 to 6000 lbs. The rails are so arranged at the top that the contents of the skip are automatically dumped into the hopper on the arrival of the skip at the top. The skip-car is hoisted or hauled to the top by a two-cylinder engine, with a friction-clutch drum, placed at the foot of the bridge, and the skip is lowered to the bottom for refilling by means of a powerful foot-brake, without reversing the engine. The top hopper is covered by a conical built-up structure, with an opening about 4 feet square. It is equipped with explosion doors, and rests on the top ring of the furnace, and covers the bell and hopper. The bell is lowered or raised by means of a simple device under the control of the operator. The distributor is a cone-shaped built-up structure, with an oval spout leading out underneath it and at one side, the top of the distributor being equipped with an annular gear. The distributor is supported on steel rollers or ball bearings, and these bearings in turn are supported by the conical built-up structure which rests on the top ring of the furnace. As each trip of the skip is made, this distributing cone is revolved a certain portion of an entire revolution by means of suitable gearing connected with the hoisting mechanism, and engaging with the ring on the cone.

An elevation and photographic view of Brown's furnace hoist with stock-distributing hopper, and of the hoisting engine, have been published.*

Transport of Materials to Blast-Furnaces.—In a paper read before the *Verein deutscher Eisenhüttenleute*, E. Schrödter † considered the question of the savings that can be effected in the cost of transport of the raw materials used in iron smelting. Everything connected with iron manufacture is now-a-days being done, he observes, on a constantly increasing scale, and it is in this development of older methods, rather than in the introduction of different ones, that modern progress in iron smelting has resulted. It is difficult, he points out, to grasp the quantity of material that has to be transported to keep in blast a furnace making, say, 250 tons of pig iron per day. This necessitates the removal of some three times its weight of iron ore and limestone,

* *Iron and Coal Trades Review*, vol. lix. pp. 1044-1046.

† *Stahl und Eisen*, vol. xx. pp. 6-24; 7 illustrations and tables.

and of an equal weight of coke, that is to say, of a thousand tons in all every twenty-four hours, a quantity which for its removal would need a train of a hundred 10-ton trucks. The number of workpeople that such a furnace gives employment to outside the works amounts to:—

	Workpeople.
In winning 675 tons of ore per day and 75 tons of limestone	618
In winning and coking 355 tons of coal per day	535
Employed in transport on railways, &c.	47
	<hr/> 1200

These figures are based on statistics relating to Germany. The ironworks itself would give employment to some 180 men, so that a furnace having a daily capacity of 250 tons would give at present employment in all to about 1380 men. It is evident, therefore, that improvements are possible. The author deals in detail with the directions in which such improvements are capable of being perfected, referring especially to German practice. The waggons used for transport purposes are capable, with advantage, of being greatly increased in size. Thus sixty wooden trucks of 25 tons capacity carry the same amount of ore as thirty 50-ton steel waggons, but the former weigh 750 tons as compared with a weight of 398 tons for the steel trucks. That is to say, the engine has 352 tons less to draw when steel waggons are employed than when wooden ones are used. The first cost of both kinds of waggons is much about the same. The average actual weight of the 15-ton coal-truck common in Germany cannot, the author observes, be much less than half the weight of the coal carried. The repairs of these large steel waggons, so commonly employed in the United States, are stated to be but slight. The record in the size of trains appears to be held by the Illinois Central Railway, in which a 106-ton locomotive draws not less than 2800 tons of total, or 2000 tons of effective load, with a train velocity of about 10 miles an hour. The train costs for this are stated to amount to 1 dollar 29 cents per mile, say 5s. 4½d. The author deals further with the state of affairs in the United States, and makes comparisons between it and the practice existing in Germany. He shows how great in the former country are the reductions in railway transport charges that have been made in recent years, and also on the Great Lakes. The effort has been most marked in the United States to combine under one management both iron ore mines, collieries, transport arrangements, and ironworks. Between them four iron-producing companies which the author names anticipate producing some 7½ to 8 millions of tons of steel in 1900,

and this entirely independent of all exterior sources of raw material, and to a large extent independent also as regards means of transport by water as well as by railway. Canals are especially dealt with, particularly as applied to Germany, where the development of water transport is a question of much importance. The connection between the iron production of a country and its political importance is shown by the author. An important discussion ensued on the reading of the paper.

Hot-Blast.—Illustrations are published * to show a method of heating blast by utilising the heat of the slag from the furnace, devised by S. E. Bretherton, and for some time past successfully used at Silver City, New Mexico. The blast is passed through flues heated by radiation from the slag.

Hot-Blast Valves.—Recent designs of hot-blast and chimney valves for blast-furnace stoves by J. Kennedy are illustrated.† The hot-blast valve has a removable seat held from the outside by clamps, and a hollow body and stem through which water is circulated. The stuffing-box for the stem has a hollow extension, which is supplied with cold air, which is allowed to leak down the sides of the stem so that dust is not carried into the gland. The chimney valve has a water-cooled seat and cover, and a soft washer on its stem which closes the cover when the valve is down.

Blowing-Engines.—The Riedler-Stumpf valves for blowing-engines and air compressors have been described, ‡ and some tests of them given as made at Donawitz, Eisenerz, Haspe, Witkowitz, and Kneuttingen.

F. W. Lürmann§ draws attention to an account of a new valve for blowing-engines. This is especially designed for engines of high speed driven by gas-engines.

Slag Ladles.—A further illustration|| has appeared of a tilting slag ladle, with the leading dimensions. The ladle proper is $7\frac{1}{2}$ feet deep, $6\frac{3}{4}$ feet in diameter, tapering to 4 feet 11 inches at the bottom, and holds 9 tons of slag. It is carried by trunnions on a steel truck,

* *Engineering and Mining Journal*, vol. lxxviii. p. 604.

† *Colliery Guardian*, vol. lxxix. p. 302.

‡ *Iron and Coal Trades Review*, vol. lix. p. 761.

§ Paper read before the American Society of Mechanical Engineers; *Stahl und Eisen*, vol. xix. pp. 1052-1054; 10 illustrations.

|| *Engineer*, vol. lxxxviii. p. 489.

which is 13 feet 3½ inches in length, and the height to the top of the ladle is 8 feet 7 inches. The total weight when loaded is 21 tons.

The Uehling and Davis Casting Machines.—E. A. Uehling* describes his method of casting and conveying pig iron. So long, he observes, as the output of a blast-furnace did not exceed a hundred tons a day, and the average output did not exceed fifty, it was comparatively easy to clear away the pigs after each cast and to prepare the pig beds for the next one. Doubling the production means, however, increasing fourfold the difficulties of such work, and consequently, as the blast-furnace outputs began to increase rapidly, the difficulties connected with getting rid of the metal obtained from the casting beds became greater and greater at an increasingly rapid rate, and in many cases skilled manual labour is not obtainable in adequate quantity. To get rid of all such difficulties the author has designed his casting appliance and conveyor.

The author first refers to the efforts made in this direction at the Duquesne Works, where the average daily out-turn to be dealt with from each blast-furnace was 500 tons. Here very large pigs were employed, and electric cranes were erected to control the whole bed and then deliver the metal to mechanical breakers, the broken pigs being discharged into railway waggons. The efforts made by J. Scott, manager of the Lucy furnace, are also mentioned. His method consisted in granulating the iron by running it into 15-ton ladles and then bringing these over a tank filled with water some 13 feet in depth. The granulated metal was then sifted out mechanically and transferred to railway waggons. At first this method seemed successful, but it was soon found that the glass-hard pellets and needles of metal so damaged the bucket conveyor that the method became impracticable. In addition, it was also found that this finely granulated metal was very liable to oxidise, and further, that it was more expensive generally to handle the metal in so fine a state of division than when it was in the form of pigs. When these experiments failed, and the electric crane arrangements of the Duquesne furnace were also found to be far from completely satisfactory, the apparatus patented by Uehling was tried, an experimental plant being erected at the Lucy furnace. When this was found satisfactory in principle, a machine was built that was to deal with the whole output of the two blast-furnaces, some 700 to

* Paper read before the Eisenhütte Düsseldorf, Dec. 9, 1899; *Stahl und Eisen*, vol. xx. pp. 25-32, with 7 illustrations and 1 plate; *ibid.*, pp. 104-107.

750 tons a day. As this machine still left something to be desired, a third was built. From the very commencement it worked faultlessly, and dealt with the whole output regularly and without any interruptions. A year of continuous work showed that a saving of 10·6 cents per ton had been effected. For more than a year the Carnegie Company has provided all its blast-furnaces with these machines, while at other works in the United States thirteen are now erected and six in course of construction. In the United Kingdom one machine has been constructed, but this will have to be rebuilt, the author says, before it can be discussed. In Austria two are being erected and in Germany one. The machine itself is something like a bucket conveyor, an endless series of moulds being carried by a couple of driven endless chains which run the moulds under a ladle containing the molten pig iron. From this the moulds fill regularly, and the bands advance at such a speed that the metal has sufficient time to solidify before the moulds upset and drop the pigs out. The red-hot pigs fall upon a band conveyor, which carries the pigs through a long tank filled with water, then rises, and finally discharges the pigs down an incline into trucks. The pigs are travelling through the water for five to seven minutes, and are perfectly cooled by the time they reach the waggon. The moulds used have to be carefully coated. Up to now milk of lime has been most generally employed, but clay, fine ashes, &c., mixed into a paste with water, have also been employed. The method in use for coating the moulds is described, and it is stated that for every 1000 lbs. of pig iron about 2 lbs. of lime are required, while the moulds stand from 3000 to 4000 charges. Other details are also appended. The power required is very small.

In the discussion which ensued on the reading of this paper, A. Post * described the Davis apparatus. He observed that he had visited the United States and seen the Uehling machine in operation at Pittsburg, where it was working in a very satisfactory manner, and was certainly doing the work required of it, which consisted in taking away from the blast-furnaces large quantities of molten pig iron, cooling it, and discharging it uninterruptedly and free from sand into the railway waggons. The time from the furnace to the waggon was about twenty minutes.

The author has since seen the Davis machine for the same purpose, and considers that this possesses several advantages over the Uehling apparatus. In the first place, it takes up much less room, the long

* *Stahl und Eisen*, vol. xx. pp. 104-105.

continuous bands of the Uehling machine having a working length of about 131 feet, whereas the Davis machine consists of a revolving table only 50 feet in diameter. The latter, too, is only half the price, the former costing about £6000, and the latter only £3000. The Davis machine is almost certain to require considerably less labour. The speaker considered the Uehling machine, which consists of continuous chain bands and is driven by chain gearing, to be much more complicated in this direction, and more likely to get out of working order than the Davis machine, the latter being driven by merely a small toothed wheel. In the middle of the Davis table a workman stands, and being only 25 feet from the casting spot on the one hand, and the same distance from the discharging point, he has the whole process completely under control should anything unforeseen occur. This control is not so readily exercisable in the case of the Uehling apparatus. All the parts of the Davis machine are extremely simple, and can be so readily replaced if broken or damaged, that the metal in the ladle would not have grown cold before the apparatus was stopped, repaired, and at work again. The moulds are some 144 in number, and are placed at the extreme edge of the table. They are of iron, and the spaces between the moulds are kept carefully covered over during the casting process. Each mould carries on its outside an arm, which, on the revolution of the table, strikes against a bar and upsets the mould. The solidified ingot drops on an endless transport band. The mould is thus automatically sprinkled with lime-water. The mould itself has four charging spaces, and each time one of these is used, and then sprinkled with lime-water, the mould is automatically turned round 90°, so as to bring a second of the charging spaces under the ladle, and not the one which had just been used. Each space has therefore an adequate time for drying before it is again used. The rotation of the table takes some seven or eight minutes. The conveyor is described, and other details also given.

This comparison is controverted by Uehling,* who also states that the cost of his machine is considerably less than that stated. The last two of his machines that were erected in the United States cost, including the three 20-ton ladles, less than £2800. These were double machines, capable of dealing with 1200 tons in twenty-four hours. This was before the late rise in price of material and labour, but even now a single machine capable of dealing with 600 tons a day would cost less than £3000, including ladles.

* *Stahl und Eisen*, vol. xx. pp. 105-106.

The Utilisation of Blast-Furnace Gas.—Bryan Donkin* in a series of articles deals with the utilisation of blast-furnace gases for power in gas-engines. During 1895, experimental engines were started successively at the Glasgow ironworks by Thwaite, at Seraing in Belgium by the Société Cockerill, and at the Hoerde works in Westphalia. At the latter place the Oechelhauser engine was used, a two-cycle motor with two pistons working in opposite directions in the one cylinder, and of this engine plans and description are given. At Seraing, the Simplex engine of Delamare-Deboutteville and Malandin is used, and plans of these engines used for driving the blowers, &c., at the Differdingen works and the Seraing works are given. Illustrations are also given of the 1000 horse-power gas-engine made by the Gas Motoren Fabrik at Dentz, and the 600 horse-power engine made by the Cie. Française des Moteurs à Gas. Further illustrations show the 100 horse-power gas-engine at the Donnersmarck ironworks in Silesia, a 500 horse-power engine made by Crossley Bros., and a 250 horse-power Stockport engine. Details of these several engines and of others are given, and the whole question is dealt with generally from the gas-engine standpoint.

C. H. Robertson† has given the results of an efficiency test of a 125 horse-power gas-engine.

An illustration has appeared‡ of the 600 horse-power gas-engine using blast-furnace gas and driving a blowing-engine at Seraing. The cylinders are tandem and horizontal, that for gas being 51·18 inches in diameter, and the air cylinder 66·90 inches. The stroke is 55·12 inches. A fly-wheel $16\frac{5}{12}$ feet in diameter and weighing 35 tons is driven by a connecting rod from the gas end.

Other particulars and illustrations of gas-engines at Seraing driven by blast-furnace gas have appeared.§

H. Allen|| deals with the production and use of power from blast-furnace gas. The conditions affecting the use of this gas for firing steam-boilers are given, and it is shown how they are overcome in the gas-engine. The objections that were previously made to gas-engines are also shown to be of small account at the present time.

An illustration is published¶ of a powerful blowing-engine for

* *Engineer*, vol. lxxxviii. pp. 509, 561, 568.

† Paper read before the American Society of Mechanical Engineers; *Engineering*, vol. lxi. pp. 135-140.

‡ *Engineering*, vol. lxi. pp. 87-88.

§ *Revue Universelle des Mines*, vol. xlviii. pp. 307-308.

|| Paper read before the South Staffordshire Iron and Steel Institute, April 1900.

¶ *Stahl und Eisen*, vol. xx. pp. 34-36.

the Differdinge Ironworks. It is driven by blast-furnace gas and is of 600 effective horse-power. It is direct acting, and was put into operation on November 20, 1899.

A comprehensive article on the progress that has been made in the use of blast-furnace gas for driving gas-engines has also been published,* and the use of such gases in the generation of electricity is discussed.†

The progress in the construction of gas-engines is described by Körting‡ with special reference to the employment of blast-furnace and coke-oven gases.

The First Coke Blast-Furnace on the Continent.—H. Wedding§ publishes an account of the life of Johann Friedrich Wedding which is of historical interest, as it throws light on the earlier iron industry of Germany. Bloomeries only had been in use up to almost the middle of the eighteenth century, and then became gradually replaced by blast-furnaces and fineries. In 1750 the total out-turn of 14 existing charcoal blast-furnaces, 40 fineries, and 31 bloomeries was about 1600 tons of bar iron. Frederick the Great caused some ironworks to be erected, which the author identifies, and in 1779 the same king forbade the importation of Swedish iron with a view of assisting the Silesian iron industry. It was in this year that Johann Friedrich Wedding entered the Prussian Civil Service, and the author briefly sketches his career, and shows how considerable was the influence he exerted in furthering the iron industry of his day. It was largely due to his efforts, amongst other causes, that the Königs-hütte was so successfully put into operation. The coke blast-furnace erected at this works was the first that was erected on the Continent to use coke alone as fuel. He was also prominently connected with the Gleiwitz Foundry.

Systems of Selling Pig Iron.—G. H. Hull|| describes and discusses the various methods of selling pig iron by the syndicate system in Germany, the warrant system in Great Britain, and the agency system in America. Some discussion has ensued.

* *Dingler's Polytechnisches Journal*, vol. cccxv. pp. 281-287.

† *Electrical Review*, December 15, 1899.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlv. p. 192.

§ "Johann Friedrich Wedding." Berlin, 1899.

|| Paper read before the Associated Foundrymen's Association.

II.—CHEMICAL COMPOSITION OF PIG IRON.

A Peculiar Efflorescence upon Pig Iron.—B. F. Fackenthal* describes a peculiar efflorescence which has been observed on the fractured surface of pig iron broken hot. In most cases the material was found in small globules and in thin sheets. Analysis of the efflorescence gave results as follows :—

	Per Cent.
Silica	94·87
Oxide of iron	0·98
Oxide of manganese	0·25
Lime	none
Magnesia	none
Titanic acid	0·95
Loss on ignition	2·87
Total	99·92

Analyses of the ores are given, and also the following analysis of furnace cadmia :—

	Per Cent.
Silica	0·55
Ferric oxide	1·40
Oxide of zinc	97·25
Carbon by difference	0·80
Total	100·00

Some lead was also recovered.

Pig Iron made from Titaniferous Ores.—A. J. Rossi† quotes a number of opinions from various authorities who have dealt with the smelting of titaniferous iron ores, and with the subsequent use of the iron so made. It is shown that only a small amount of the titanium is reduced, and that though the metal may not be suitable for the foundry, yet it serves exceedingly well for forge and steel purposes. Incidentally his own experiments are mentioned.‡

Pig Iron from Lombardy.—Pig iron§ made in the Seria Valley had the composition :—

Comb. C.	Graphite.	Si.	S.	P.	Mn.
0·45	3·25	0·987	0·026	0·050	1·26

* *Transactions of the American Institute of Mining Engineers*, February 1900.

† *Engineering and Mining Journal*, vol. lxix. p. 284.

‡ *Journal of the Iron and Steel Institute*, 1896, No. I. p. 401.

§ *Studio sulle condizioni dell' industria siderurgica in Lombardia*. Rome, 1899.

A good deal of the ore found is the carbonate. Iron ore from the Upper Scelve Valley containing 45 per cent. of iron yielded a white pig iron containing:—

Comb. C.	Graphite.	Si.	S.	P.	Mn.
2.16	1.125	0.666	0.060	0.035	1.64

Ore from the same valley, and averaging about the same percentage of iron, yielded in the Schilpario blast-furnaces pig irons of the composition stated below, using about 0.8 ton of charcoal per ton of pig iron made:—

	Comb. C.	Graphite	Si.	P.	Mn.
White . . .	0.02	1.73	0.70	0.00	2.52
Mottled . . .	1.10	1.42	1.01	trace	2.35

Ores from the Lake Iseo district gave a grey special pig iron containing:—

Comb. C.	Graphite.	Si.	S.	P.	Mn.
0.48	0.51	3.31-2.88	1.11-0.981	0.032-0.073	1.84-1.70

The local ores smelted at the Govine-Pisogne blast-furnace on Lake Iseo yield a manganiferous pig iron. The following is stated to represent the composition of this ore:—

MnO.	SiO ₂	Al ₂ O ₃ + CaO + MgO.	S.	P.
6.8-7.6	10-20	7.4-15.7	8.02-0.04	traces

The white pig iron made from this ore contains:—

Comb. C.	Graphite.	Si.	S.	P.	Mn.
2.95-2.75	0.35-0.42	1.08-0.82	0.10-0.07	0.052-0.047	2.18-2.20

Other analyses of pig iron made at different furnaces are also given.

III.—BLAST-FURNACE SLAG.

Utilisation of Blast-Furnace Slag.—A. D. Elbers * describes bricks made of slag wood, with the addition of about 2 per cent. of cementing material. These bricks are used as insulators or non-conductors for heat or sound, and can be shaped to meet various requirements. They can be made to weigh about 28 lbs. per cubic foot, and will endure a load of 54 lbs. per square foot without permanent set.

The manufacture of Portland cement from blast-furnace slag by the

* *Iron and Coal Trades Review*, vol. ix. pp. 259-260.

Forell method is considered by Kämmerer.* The increase in the production of pig iron has been so great, and the quantities of slag produced consequently so large, that former methods of utilisation of slag did not keep pace with the production. Other methods had, therefore, to be sought for, and the close resemblance between the composition of a basic blast-furnace slag and cement led to its being employed for building purposes in various ways. The bricks produced from granulated slag, to which a little lime has been added, are very strong, and form a very useful material for building construction. It is in the direction of cement manufacture, however, that most has been done. The first utilisable slag cement consisted of dried and ground blast-furnace slag with an addition of hydrated lime. This product did not resemble Portland cement in colour or weight, or in the way it hardened. Still it was too dear, and granulated blast-furnace slag does not readily give up the water it has absorbed during the granulation process, and neither is it easy to grind fine. This drying and grinding of the slag makes the cement expensive. To avoid this, attempts were made to mix the molten slag as it came from the blast-furnace with powdered lime. A product of irregular composition resulted, however. The next efforts were directed towards making an imitation Portland cement. For this purpose slag and limestone were dried, ground, mixed in proper proportions, made into bricks and burnt. When subsequently again converted into powder, the product was Portland cement. This necessitates, however, the use of costly plant. A new method, by Forell, has now been introduced at iron-works at Lollar in Upper Hesse. This is very simple in character. It utilises a kiln of special construction, the waste gases from which first heat the slag and limestone to a considerable temperature, and so facilitate very greatly the subsequent grinding. The ground material is mixed and burnt as powder, without, that is, being first moulded into bricks. Lumps form during the burning, but these can readily be ground fine. The product forms a Portland cement of excellent quality.

* *Stahl und Eisen*, vol. xix. pp. 1087-1088.

IV.—*FOUNDRY PRACTICE.*

Foundry Appliances.—J. Horner* deals generally with the equipment of the modern foundry, and gives a number of illustrations drawn from European and American works, showing sand-mixing, flask conveyors, loam-foundry, core-oven, casting and cleaning rooms, moulding machinery, &c.

J. Cherrie† gives a sketch of the four foundries which were at work in Johannesburg before the war.

Numerous illustrations of a new foundry at Watertown, Massachusetts, have appeared.‡

A plan and description has been published§ of the foundry and machine works at Harrisburg, Pennsylvania.

Amongst a series of articles on American competition is one by W. J. Keep|| on the production and use of cast iron stoves in the United States.

Cupola Practice.—J. C. Mears¶ discusses the use of oxide of iron or of rusty iron in the cupola, and shows that it should, as a rule, be avoided. It is not reduced to any valuable extent, but it acts on the silicon and lowers its percentage, therefore being prejudicial. It is only useful when limestone is not used and there is much sand present, as then it makes the slag more fusible.

Illustrations have appeared** of a cupola lined with the cast iron hollow bricks devised by A. Eadie, which has been at work for over a year. The bricks are laid to break joint, and form air passages upwards from the lower part of this lining, which commences 4½ feet above the centre of the tuyeres. No refractory material is used between or on the exposed faces, where they are submitted to the rising gases, but despite this they show no signs of fusion or wear. The thickness of metal on the exposed faces is one inch, and the bricks are kept cool by air from the blast.

* *Cassier's Magazine*, vol. xvii. pp. 300-316.

† *Foundry*, through the *Iron and Coal Trades Review*, vol. lix. pp. 1043-1044.

‡ *Iron and Coal Trades Review*, vol. lx. pp. 357-362.

§ *Iron Trades Review*, March 1, 1900, pp. 14-17.

|| *Engineering*, vol. lxi. p. 77.

¶ *Iron Trades Review*, December 28, 1899, p. 20.

** *Engineer*, vol. lxxxix. p. 301

Foundry Iron.—According to H. Pilkington,* foundry iron ought to receive as much investigation and examination, both chemical and physical, as that bestowed on steel. Much careful and painstaking experimental work is required as to the specific behaviour of foundry iron in the foundry; mere chemical analysis is not sufficient, and, indeed, of itself might be misleading. In a general way, to produce the largest possible percentage of foundry iron, the foundry furnace must be working and driving with steady regularity. The more total carbon there is in foundry pig iron the more satisfactory is its behaviour in the foundry in all practical operations of melting, pouring, and casting. High carbon iron can only be made under what might be called happy conditions at the blast-furnace—a hot furnace, great regularity, large casts, plenty of well room, quick tapping and running, fast driving, fuel low in sulphur, silicon in iron moderate, manganese and phosphorus low. For many general purposes, for the sake of fluidity and clearness, phosphorus is useful up to $1\frac{1}{2}$ per cent. and manganese up to 0.75 per cent., but if strength is required, the phosphorus should be low, not the carbon. Analysis has not yet been sufficient for the sampling of foundry iron. Casting in sandbeds at the furnaces is very far from being an ideal method of dealing with iron, and the subsequent handling and loading up of the pigs by costly and difficult labour ought to be abolished; but when it comes to foundry iron, sandbeds have advantages. It allows the carbon to arrange itself in such a form that it records when a pig is fractured, how it has been treated, and whether or not it is in a stable condition. In America the casts are large, often 70 to 80 tons, and the proportion of foundry iron, over long periods, averaging 85 to 90 per cent. Every day the phosphorus, manganese, and sulphur are determined, in many cases in every bed, always at least in each number in each cast. Every cast is numbered and kept separate. The iron is sold by number with a definite percentage of silicon. It could be seen stacked up in yards, and painted with its number and silicon. Foundry work is more specialised than in England. All castings for machinery are generally much softer, and in a machine-shop the castings are machined with much greater rapidity. Generally speaking, the silicon in American castings is lower than it is in England and greater attention is paid to cupola practice, temperatures of castings, sizes of feeding bends and feeding, methods of skimming and pouring, and sizes

* Paper read before the South Staffordshire Iron and Steel Institute, Jan. 20, 1900.
1900.—i.

of gates and risers. In some classes of castings and foundry iron, however, the English can surpass the Americans. In every case of foundry iron there is of necessity much difference in the composition of the different parts of it, due mostly to the different rates of cooling after it left the tap-hole. The sampling of iron for analysis, unless the fracture is taken into account, is most precarious, and the analysis often represents nothing except just the specific lot of drillings taken. The carbon is the truest guide; and the author has a preference for sampling by fracture, and making analysis of the specific numbers. He is of opinion that the influence of silicon has been vastly overrated. As a rule, there is quite enough silicon in most English foundry iron—*i.e.*, in that intended to be soft foundry—to actually harden iron. Silicon is always a weakness both in castings intended to be strong and those intended to be soft. Very soft castings can be made, and are made, with very low silicon. In cheap castings, where strength matters little, silicon makes the iron fluid, and it will run up well; phosphorus will do the same thing; both do some of the work of carbon at a cheaper cost, and they are both hardeners and weakeners.

J. E. Johnson, jun.,* deals generally with the chemistry and physics of cast iron. For castings he considers the analysis more important than the fracture, as iron cast in chills, if of the same composition as sand-moulded pigs, will produce satisfactory work. The action and interaction of the carbon, manganese, silicon, sulphur, and phosphorus in iron are then briefly reviewed, and it is suggested that the average analysis for general foundry work should show :—

Silicon.	Sulphur.	Phosphorus.	Manganese.	Combined Carbon.	Graphitic Carbon.
1.40	0.03	0.5	0.6	0.4	2.5

E. H. Putnam † discusses some of the causes of hardness in castings and similar matters, especially in reference to the nature of the iron and the moulds employed.

S. B. Marshall ‡ also deals with the effect of the various elements, and gives some particulars of radiator castings.

E. Kirk § discusses the fracture of pig iron as an indication of its value for foundry work, and shows how useful it is when judged by an expert; but the really capable men are rare. It is impossible to

* *American Machinist*, vol. xxiii. pp. 316, 342.

† *Iron Trade Review*, February 8, 1900, p. 7.

‡ *Ibid.*, March 15, 1900, pp. 16-17.

§ *Ibid.*, February 15, 1900, pp. 14-15.

describe or illustrate the fractures, or their special features, which are relied upon, and the whole question may be put down as being one of knack rather than anything else. Certain general statements are, however, made for guidance. The author's position is attacked by T. D. West.*

A series of letters dealing with the position and duties of the chemist in the foundry have appeared.† The contributors who started the discussion were E. Kirk and T. D. West; and many others have contributed.

Malleable Castings.—E. H. Putnam‡ thinks that analysis may be left to the blast-furnace people, and that the essentials for starting a malleable casting foundry are a practical knowledge of moulding, founding, and annealing. Other notes on the practice of malleable iron manufacture are also given by the same author.§

G. C. Davis|| has given the results of some experiments on the increase in size and weight of malleable castings after annealing in mill scale. The increase is due to the reduction of iron from the packing, and does not occur when the material used is sand. The average gain in weight in three instances was 6·29 per cent., or, allowing for the loss of carbon, 9·69 per cent. The increase in the cubic contents of tested bars ranged as high as 10 per cent., and is largely due to the reduced iron welding on to the castings. Some experiments with sulphurous irons were also made, and it was shown that the castings absorbed sulphur from the packing.

H. M. Howe¶ comments on the results obtained, and suggests that the increase of bulk may be due to the change from cementite into ferrite and temper-graphite.

C. James** deals with the annealing of white cast iron, giving the results of observations made in actual practice. The castings annealed weighed from a fraction of an ounce to several thousand pound pieces. He points out that silicon is a necessary element in annealing, and that manganese materially shortens the time in effecting the change

* *Iron Trade Review*, February 22, 1900, p. 11.

† *Ibid.*, January 18, 1900, p. 10; January 25, p. 15; February 1, pp. 9 and 11; February 8, p. 6; February 22, p. 13; March 1, p. 19; March 15, pp. 12 and 14; March 22, p. 16; March 29, p. 16.

‡ *Tradesman*; *Iron Trade Review*, October 19, 1899, p. 15.

§ *Ibid.*, December 28, 1899, p. 18; January 25, 1900, p. 11.

|| Paper read before the Foundrymen's Association, March 1900.

¶ *Engineering and Mining Journal*, vol. lxi. p. 382.

** *Journal of the Franklin Institute*, November 8, 1899.

in the state of the carbon. Sulphur has also a marked effect, but no positive information can be given of the exact part played by it. The annealed castings are much stronger than ordinary cast iron, both in compressive and tensile strength, showing as high as 50,000 lbs. tensile strength. The resistance to wear is also considerably greater than ordinary cast iron.

Moulding.—L. C. Jewett* describes the methods of making and using follow boards in the foundry for moulding purposes. Plaster, litharge mixed with sand, and wood are used.

In a series of articles dealing with a comparison of British and American machine tools, the question of moulding machinery is dealt with, and illustrations are given† of the Tabor and Pridmore machines.

* *American Machinist*, vol. xxiii. pp. 394-395.

† *Engineer*, vol. lxxxviii. pp. 559-560.

PRODUCTION OF MALLEABLE IRON.

The Direct Production of Iron.—H. Leobner * has published an exhaustive history of the direct production of iron and steel, in which the chief processes employed are compared and criticised. Arranged chronologically, the processes described are the following :—

Before the 19th century.—The Rennfeuer ; Catalan forge ; Corsican forge ; Stückerofen ; Count, J. von Sternberg's proposal, Prague, 1795.

The first half of the 19th century.—Maison-Desroches (1829), France ; J. Heath (1839), England ; W. Clay (1837–40), England ; Von Gersdorff (1843), Neuberg, Styria ; De Meckenheim (1842), A. Chenot (1846), France ; J. von Rosthorn (1847), Prävali, Carinthia ; F. Knowles (1849), England.

1850 to 1860.—Dr. A. Gurlt (1857), Germany ; J. Renton (1851), United States ; F. Yates (1859), England.

1860 to 1870.—Ellershausen (1869), Pittsburg ; A. Chenot (1866), France ; T. Blair (1868–70), United States ; Sir C. W. Siemens (1868), London.

1870 to 1880.—Sir C. W. Siemens (1871), Sir C. W. Siemens (1873) ; C. Kazetl (1875), Neuberg ; Gerhardt (1874) ; Sudre (1876) ; J. Reese (1877), United States ; T. Blair and Schönberger (1878), United States ; Du Puy (1878) ; Justice (1879).

1880 to 1890.—Sarnström (1882), Sweden ; K. and H. Leobner (1883–88), Vienna ; W. Schmidhammer (1886), Hungary ; C. Husgavfel (1886–87), Finland ; C. Eames (1886), United States ; O. Thiéblemont (1883), France ; Wilson (1884), United States ; H. C. Bull (1882), Seraing, Belgium ; L. Cely ; Thwaite ; A. Hansen (1885), Dortmund ; F. Siemens (1885–87), Dresden ; J. Shedlock (1884–86), England ; A. Fritsch (1886), Paris ; Chemical Company of St. Denis (1886), Paris ; H. Cowles (1885), United States ; H. Eames (1889), United States.

1890 to 1900.—J. G. von Ehrenwerth (1890), Leoben ; M. Conley and J. Lancaster (1891), United States ; C. Adams (1891), Pittsburg ; D. Danton (1891), Paris ; G. Jullien (1892), Lyons ; W. Carty (1890),

* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xlviii, pp. 219–261.

United States ; F. Siemens (1892), Dresden ; J. von Langer (1892), Léeds ; W. Berner (1894-97), Russia ; C. Otto (1896), Dresden ; E. Servais and P. Gredt (1896-99), Luxemburg ; H. A. Jones (1897), United States ; Carbon Iron Company (1897), Pittsburg ; T. Schönberger and Blair (1893), United States ; A. Dauber (1889), Bochum ; De Leval (1897), Sweden ; Borchers (1898), Germany ; Stassano (1899), Italy ; H. Niewerth (1897), Berlin ; and D. Tschernoff (1899), Russia.

Particulars have been given* of the Stassano electric furnace at Darfo. With 3000 horse-power a ton of iron or steel can be made per hour, or 7000 tons a year.

Native Iron Manufacture.—W. H. Shockley, in an appendix to a report by J. G. H. Glass† to the Pekin Syndicate, describes at some length the native methods of iron manufacture in the provinces of Shansi and Honan in China. A rough estimate places the out-turn of iron in Shansi at 50,000 tons annually as a minimum. In 1870-72 Von Richthofen estimated it at 160,000 tons, but the trade has greatly declined since then.

At Emyrne, in Madagascar, there are twenty-five native hearths making iron from ore containing up to 75 per cent. of the metal, but poorer and softer ores are preferred. The furnace is 2 to 2½ feet in diameter and 2½ to 3 feet in height, with a single tuyere and a slag-hole on the opposite side. The charge is about 4 cwt., and the metal produced about 1½ cwt. in seven to eight hours. Refining is effected in a similar furnace with subsequent hammering to expel the cinder.‡

F. Hupfeld§ describes the iron industry of the German Togo District, Africa. On the east of the colony, from the north to the coast, approximately along the frontier of French Dahomey, are the Monuebene Mountains. These are archæan, and farther west are crystalline slates. Still farther to the west is a zone of quartzite. Iron ores are found in the slates. There are signs in many places of a former iron industry, but now iron ore is mined in two districts only. In one of these, the Basari district, the ore is found in quartzite. After being hand-picked, a sample of ore contained :—

Fe_2O_3	SiO_2	P_2O_5	H_2SO_4
98·43	1·54	0·03	trace

* *Revista Minera*, vol. li. pp. 116-117.

† November 1899.

‡ *Engineering*, vol. lxi. p. 89.

§ *Mittheilungen aus den deutschen Schutzgebieten*, 1899, Part IV. ; *Stahl und Eisen*, vol. xx. pp. 347-351.

This is equivalent to 68·90 per cent. of iron. There was no manganese in the ore. It will be seen that the ore was of a most exceptional degree of purity. The Kabu hill is another deposit of red hæmatite. The hill consists entirely of iron ore, but this is more siliceous in character than that mentioned above. The natives smelt these ores with charcoal made from various kinds of trees in meilers some 6 feet in width. The native iron furnaces are round and remarkably like an ordinary blast-furnace in shape. They have a number of tuyeres and a working hole at the base. These the author describes and illustrates, the method of working being also described. The furnaces are of considerable height, one, of which dimensions are given, being over 11 feet high and nearly 2 feet in maximum width. Layers of charcoal and iron ore are charged in, and in the Basari and Sara districts a charge of 0·120 ton of iron ore, containing 0·084 ton of iron, yields in three days a bloom weighing about 0·030 ton, but which only contains about 0·020 ton of useful iron. That is to say, 84 lbs. of iron in the ore only yields 20 lbs. of useful metal, a yield of about 24 per cent. The natives make considerable use of this metal. At Banyeri, in Northern Togo, there are hundreds of such furnaces, but only a few are at work.

In the second district previously referred to, that of Boem in Central Togo, several lenses of red hæmatite are known, as well as other deposits. The following is an analysis of some ore from this district :—

Fe_2O_3 .	SiO_2 .	P_2O_5 .	H_2O .	H_2SO_4 .
78·4	10·5	0·73	9·98	trace

Again no manganese was present, and no carbon dioxide, and it will also be observed that the percentage of phosphorus is considerable. The red hæmatite is mixed with laterite and brown ironstone.

In this district the charcoal is made in circular meilers, about 12 feet in maximum diameter and 3 feet in height. The pieces of wood to be converted into charcoal are about 2 feet long and 4 inches in thickness. They are piled on one another in such a way as to leave an opening in the middle a foot in width. The space at the periphery is filled in with waste material, the meiler then assuming the shape of a round, low cupola. Red-hot charcoal is then thrown into the central space, and when the heap is alight, a layer of green twigs about a foot in thickness is thrown over all as a cover, and then on top of this a similar thickness of grass, a coating of earth being put on the top of all. The method of firing the heap is described in detail. The furnaces used closely resemble those employed in the other district. The tuyeres are six in number. In firing the furnace, about 120 lbs. of charcoal are first charged in, and

then 44 lbs. of iron ore broken down to "nut" size. The furnace is got into fire by blowing through the tuyeres by bellows, these being subsequently removed and natural draught alone employed. We have here the first stage in the transition towards the forced blast. In the course of seventeen hours the ore has been reduced, and is found in the form of a bloom on the bottom of the furnace. The working opening is then rapidly opened and the slag removed, water being squirted in. The slag weighed about 29 lbs. in the case referred to, and the bloom about 10 lbs. This bloom still contained over 30 per cent. of slag. A sample of the iron carefully freed from slag was found to have the following percentage composition :—

Silicon.	Carbon.	Phosphorus.
1.11	0.08	0.34

The iron slag contains :—

FeO.	SiO ₂ .	P ₂ O ₅ .
63.8	29.78	0.57

Some of the slag had become pasty in the furnace, and was removed as a half-solidified lump. On being analysed this was found to contain :—

FeO.	SiO ₂ .	P ₂ O ₅ .
19.82	77.55	0.19

For each pound of iron produced the quantity of charcoal used was as much as 18 lbs.

The author then gives an interesting account of the native workers in iron, as well as of the smithies used and the tools employed. A quartzite block is used as the anvil, and the hammers in use are also made of this material. Slaves are not allowed to become smiths, and the whole industry is kept very secret.

Puddling.—The direct puddling process is in use at Hourpes, near Thuin.* A 35-ton pig iron mixer yields fluid metal to adjacent puddling furnaces, which are capable of treating 100 tons a day. The mixer is heated by the gases from two small producers, a ton of coal being consumed for this purpose in twelve hours. The puddling furnaces are modified open-hearths, and are gas-heated. Such gas-heated puddling furnaces give better results with molten metal than with solid pig iron. The details of the process in use are given.

M. Verstraete † gives a detailed account of each of the principal iron

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 620.

† *L'Oural*, Paris, 1899.

and steel works of the Urals. The puddling process is still very largely employed.

History of Iron.—According to A. Ditte,* iron was little known to the Egyptians; it was, however, used here and there. On monuments it is painted blue. It was rare, for helmets and breastplates were made of a body of copper covered with bands of iron. Among the Chaldeans, on the other hand, iron was very abundant. In the palace of Khor-sabad, for example, what is called the chamber of iron was found, comprising chains, hammers, picks, chariot wheels, &c., made of excellent iron, the weight being 160 tons.

E. F. Lange,† in a recently delivered lecture, sketches the history of iron and steel from the earlier ages up to the present time, and deals more especially in a semi-popular way with the original discovery and cruder forms of early workings. The wonderful ironwork of India, of which the great column at Delhi-Laht is only one example, shows the high state of perfection that some of the artificers were capable of about the ninth or tenth century before Christ. The later processes of cementation, puddling, and steel manufacture are more briefly referred to.

A. N. Palmer ‡ has written a Life of John Wilkinson, the great iron-master, dealing more especially with the Bersham and Brymbo Ironworks. The volume is illustrated by a plan of the Bersham Ironworks estate in 1829, and photographs of the works and of the various types of tokens issued by John Wilkinson in 1787 to 1793.

* *Le Mois Scientifique et Industriel*, 1900, p. 132.

† Association of Under-Managers and Foremen, Manchester, February 17, 1900.

‡ "John Wilkinson and the Old Bersham Ironworks," 1899.

FORGE AND MILL MACHINERY.

Ironworks Plant.—H. B. Toy * describes what he considers to be an economical plant for producing approximately 1000 tons per month of merchant and guide iron bars. There are twelve puddling furnaces built in pairs, and spaced at a convenient distance apart and in two rows. Each furnace has a closed grate with forced draught, and the waste heat is used for raising steam. The designs of the steam-hammer, forge train and engine, shears, the engine and 12-inch guide-mills, the two mill-heating furnaces, and other details, are dealt with. This plant has produced, with good running orders, 1000 tons of finished iron in one month of four weeks, consisting chiefly of rounds, squares, flats, &c., from $\frac{1}{2}$ in. upwards. In single turns of twelve hours each, 30 tons of $\frac{3}{4}$ in. rounds, 25 tons of $\frac{5}{8}$ in. rounds, and 30 tons of hoops or strips, $4\frac{1}{4}$ in. wide by 11 gauge, and 30 tons $1\frac{1}{4}$ in. rounds (rolled by guide) have been produced.

Tandem guide-mills are briefly mentioned, and then sheet iron and sheet steel are discussed. A sheet iron works should have the puddling furnaces in a line similar to those in the guide-mill plant, with a good steam-hammer, quick-running forge train driven by an independent condensing engine, with heavy flywheel; also four single sheet mills, with chilled rolls 24 in. diameter, driven by two condensing engines, each capable of developing about 350 indicated horse-power, running at about 50 revolutions per minute, with a flywheel about 30 ft. diameter, 40 tons weight, fixed on the engine shaft, and a pair of massively designed helical teeth wheels supplied to reduce the speed of mill shaft to 38 revolutions per minute. The bar-sheet and scrap shears are self-contained and driven by separate engines. The plan favoured for steel sheets is a pair of compound condensing engines, about 1000 indicated horse-power, running at a speed of fifty revolutions per minute, with a heavy flywheel fixed on engine shaft. Two mills are placed on each

* Paper read before the Staffordshire Iron and Steel Institute, December 16, 1899.

side of this engine, with chilled rolls 24 in. diameter, and at the end of each second mill is provided a friction wheel arrangement to avoid backlash and keep all the couplings in regular torsion. The housings of steel sheet mills must necessarily be massively designed, as the steel bars are rolled into sheets at a much lower temperature than iron, and the material will allow a more rapid reduction in thickness. The choice of mill bed-plate is discussed. Probably in the near future steel sheet bars 18 in. wide will be rolled direct from the ingot in a Universal reversing two-high mill.

Steel section mills and steel plate mills vary enormously in their design, but the author touches briefly on them, and for the latter prefers a three-high mill.

G. Beard,* in a presidential address, deals *inter alia* with the progress of plate and sheet rolling during the last sixty years. The plates for the *Great Britain* steamship were 7 to 8 feet long by about 2 feet wide, and were made from slabs hammered under a helve. Before 1854 much 24-gauge sheet was rolled direct from puddle bar, and then piling was introduced. Even now, 20-gauge sheets 4 feet wide are considered good work, but between 1845 and 1857 large quantities of sheet were made for trays, and they were even rolled 5 feet wide to fulfil a special order.

J. Fritz † deals generally with the development of iron manufacture in the United States, and naturally devotes most attention to the development of the rolling-mill, with which he is so intimately connected as the erector of the first three-high mill at the Cambrian Iron-works.

Forging Presses.—C. Sellers ‡ reviews the progress of the mechanical arts during the three-quarters of a century which have elapsed since the foundation of the Franklin Institute. The working of iron and steel, *inter alia*, and the introduction of Whitworth's process of compressing steel, and the use of the forging press in lieu of the steam-hammer are touched upon. As an example of the work done, reference is made to the steel rings 11½ feet in diameter, 5 inches thick, and 50 inches broad, used in the power station at Niagara Falls. This work was the first product of machinery intended for armour and steel ship forgings.

* *Journal of the West of Scotland Iron and Steel Institute*, vol. vii. pp. 3-8.

† *Journal of the Franklin Institute*, vol. cxlviii. pp. 437-460; *Cassier's Magazine*, vol. xvii. pp. 459-471.

‡ *Journal of the Franklin Institute*, vol. cxlix. pp. 5-25.

Two illustrations* have appeared showing the 10,000-ton forging press and plant at the Obouchoff Works at St. Petersburg. The total weight is about 1360 tons.

Ingot Stripper.—Illustrations have appeared† of Evans' ingot stripper, which has been in successful operation for some time at Cyfarthfa. It can strip simultaneously two ingots from 6 feet down to $1\frac{1}{2}$ feet long, and when fully extended it is $34\frac{3}{4}$ feet in height. The ingot is held against a central ram behind which free water is automatically shut in, when the pressure is put on by two outside rams which lift the mould. These rams are differential, to exert the greatest power at first, and then to economise water when lifting the mould clear.

Lifting Magnets.—Illustrations are given‡ of Wellman's design of electro-magnets adapted for lifting plates, bars, &c., up to a load of five tons.

Rolling-Mill Engine.—Illustrations are published§ of a large reversing rolling-mill engine, built by the Märkische Maschinenbau-Anstalt, of Wetter-on-the-Ruhr, for the steelworks at St. Chamond, France. It is intended to drive an armour-plate mill.

C. Kiesselbach|| shows the great advantages of using compound engines for rolling-mills. Owing to variable nature of the load, the point of cut-off must vary very greatly in single-cylinder engines; and as steam is often carried full stroke, the loss from clearance and internal condensation is often large; while if condensing engines are used, the sudden discharges of high-pressure steam when working under heavy loads render it difficult to maintain a satisfactory vacuum. For these reasons, compound engines have been found the best for rolling-mills. For reserve power it is advisable to use a somewhat smaller cylinder ratio than would otherwise be adopted in good practice, the value varying between the ratio of 1 : 2 and 1 : 2·3. The cut-off in the low-pressure cylinder should not be set too early, or the pressure in the cylinder may occasionally rise too high. Triple expansion engines are not so well adapted as compound engines for the purpose, since the sudden

* *Iron and Coal Trades Review*, vol. lx. pp. 502-503.

† *Engineer*, vol. lxxxviii. pp. 366-367.

‡ *Iron Age*, February 22, 1900, pp. 4-5.

§ *Stahl und Eisen*, vol. xix. p. 1107, with plate; *Echo des Mines*, 1900, pp. 337-339.

Industries and Iron, vol. xxvii. p. 282.

changes of load occur too rapidly for a change in regulation to affect all three cylinders in time. This is clearly shown on indicator diagrams. The cross compound engine with cranks at 90° has almost entirely been replaced in German mills by tandem compound engines, most of which are built with flywheels; but reversing engines are now being similarly constructed, and coming into general use.

Continuous Rolling-Mill Plant.—A composite plan of four mills employing the Morgan continuous rolling plant has been published.* The furnaces for reheating are of the continuous type, with inclined beds and a gravity discharge to save the labour of drawing the hot billets. For this purpose the pipe skids on the bed have a sharp drop near the end, and deliver the billets on to a conveyor which takes them to the rolls, where they are reduced from 4 inches square to $\frac{1}{2}$ inch square, or more as desired. Thence the bars pass continuously through a finishing mill on to a conveyor which is moving slightly faster than the bar. After the piece is finished, one end is caught by a steam stretching device and the other end by an anchor grip while the work is pulled straight. These devices are somewhat out of line with the delivery from the mill, so that the straight bar is removed to the top end of an inclined cooling bed. On this the bars are maintained by a series of fingers, which are withdrawn at intervals to allow the bars to slide down on to a receiving table, where they are cut in bundles by a shearing machine. The cooling bed is 300 feet long.

A Three-High Universal Plate-Mill.—A photographic view has appeared † of the three-high universal plate-mill erected at the Lukens Works at Coatesville, Pennsylvania. It is a 28-inch mill, designed to roll plates from 9 to 48 inches broad and up to 100 feet in length. The mill weighs 320 tons and stands 29 feet in height. It is to be driven by a 34 and 60 by 60 inch compound condensing engine.

Some particulars as to the early history of three-high rolls are given by W. G. Howell,‡ who shortly describes the different mills of that type in use in South Wales between 1852 and 1860.

Wire-Rod Rolling.—In a paper read before the Verein deutscher Eisenhüttenleute, M. Baackes§ observes that about one-eighth of the

* *Iron Age*, January 18, 1900, pp. 9-10.

† *Iron Trade Review*, March 29, 1900, p. 15.

‡ *Iron and Coal Trades Review*, vol. lix. p. 1043.

§ *Stahl und Eisen*, vol. xx. pp. 65-94; 42 illustrations.

whole of the steel produced in the world is turned into wire. This at least is the case in the United States, where between one and one and a quarter million tons of wire are produced annually. The author estimates the production in Europe and the United States taken together at about two million tons a year—a quantity it is difficult to grasp in the case of a material like wire. The history of wire production goes back into very early history. Seventeen hundred years B.C. wire is stated to have been made, and in the British Museum there is a piece of wire made by the Ninevites 800 years B.C. Until comparatively modern times such wire was made by hammering, until a time came when it was found that a better result could be obtained by drawing the metal through round holes. The metal was subsequently first rolled into a plate and then cut into thin rectangular bars, and this method remained in use until quite recent years, the author himself having seen in Belgium in 1877 an apparatus by which these bars were made, and he also saw the same bars in their cut form. These bars were chiefly employed in making nails, but were formerly worked up into wire, being first somewhat rounded and then drawn. The art of rolling iron into shapes dates back to 1783, Henry Cort being the first inventor in this field. From his invention the wire rolling-mill has developed, and the author sketches the rise and progress of the modern wire rolling-mill.

The first wire rolling-mills were erected in Belgium, and these the author illustrates. The bars were rolled backwards and forwards in a three-high mill, and the author in this connection draws attention to the definition of a Belgian wire rolling-mill, as one in which the stands of rolls are placed in the same working line. The wire-mills of Germany were all originally of distinct Belgian type. Subsequently the metal was first subjected to a preliminary rolling process, and this meant a modification of the original mill as regards additional stands of rolls. This addition constitutes the German mill as distinguished from the Belgian. Illustrations are given of this form. In those days the rolling-mills were not provided with any of the improvements which distinguish a modern mill, and consequently the wire billets were of very small size. The material, too, being wrought iron, was not such as to admit of very great lengths of wire being readily produced. As soon, however, as the introduction of the telegraph rendered it necessary to produce wires of greater length in a single piece, the wire-mill began to be improved, the continuous rolling-mill of Bedson—an illustration of which is also given by the author—being the first important improve-

ment. In this, pairs of rolls were placed before each other, and the rapid rate of rolling protected the wire from cooling during this process. Consequently longer wires became possible, and whereas before this pieces of only some 25 lbs. weight were rolled, and the daily out-turn amounted to from 3 to 5 tons, in 1867 Bedson rolled 100-lb. pieces, and obtained an out-turn of 11 tons per day. In Bedson's mill a pair of horizontal rolls was followed by another pair placed vertically. This enabled the wire to take a straight course when being rolled. In Germany, too, efforts were made to improve the process, and the author illustrates the mill erected by Böcker at Schalke. The best German wire-mill which the author has seen is that constructed by Messrs. Klein Brothers at Dahlbrück for Mont St. Martin, described by Daelen in 1889. In Sweden, too, remarkable progress was made, illustrations of the mill at Domnarfvet being given.

The author then proceeds to consider the similar progress that has been made in the United States. At first the wire industry there made but slow progress. One of the earliest of the wire-mills was that erected by the Falls River Ironworks Company in 1839, which consisted of a single three-high mill. It was burnt down in 1843. A mill is illustrated which was constructed by Ichabod Washburn in 1840 in the neighbourhood of Worcester, Massachusetts. An illustration is also given of the continuous rolling-mill patented by H. B. Comer in 1859. The subsequent progress in the United States is sketched out by the author, who deals with the subject at some length, by the aid of numerous illustrations, his own improvements being also dealt with. The Rankin rolling-mill erected by Garrett in 1885 for the Braddock Wire Company was reconstructed by the author in 1897, and within four months of its re-starting had an average out-turn of 400,000 lbs. per shift. Other important works are also dealt with, including those at Waukegan, near Chicago, and a new mill erected in 1896 by the Illinois Steel Company. The author deals with the arrangements of such mills and the furnaces accessory to them, the Laughlin automatic heating furnace being specially referred to. After dealing generally with the subject, the author observes that the form of rolling-mill in almost general use in Germany is that which is best adapted for producing the best wire, so far as the question of the shape of the wire is concerned. The cost of wire-rolling is then considered, the loss of metal being placed at from 1 to 1½ per cent. The wages paid in the United States are mentioned, the author stating that the cost of rolling a statute ton of wire at good works in the United States is from 3½ to 4½ dollars.

Re-Rolling Rails.—Experience with worn rails has shown that added serviceability of the rails could be cheaply gained at the cost of re-rolling, and in 1897 a new mill was built at Joliet, Illinois, specially equipped for the work. In this mill there are two furnaces for heating the rails, so arranged that the rails can be charged in at one end of the furnace and drawn out at the other. Each furnace has a capacity for twenty-one rails, and the time required to heat the rails to the desired temperature, 1600° F., is about thirty-five minutes. The rails are withdrawn from the furnace one at a time, and as soon as seven have been withdrawn a new charge of seven rails is run in at the other end of the furnace. Each rail, after being taken from the furnace, receives three passes in the rolls, or one pass in each of three sets of two-high rolls in tandem. From the third and last set of rolls, known as the finishing rolls, the rail emerges at a temperature of about 1400°, whence it is taken to the hot saws, hot beds, straightening and drilling machines, in the usual way. The capacity of this mill is 400 tons of rails re-rolled in twenty-four hours. In Kansas City there is another mill of equal capacity and similarly operated, built in 1898.

Before the rails are put into the heating furnace, fins or slivers, resulting from flowing of the metal, are ground off with an emery wheel, as it is found that the metal composing such imperfections is extremely hard, and if rolled into the body of the rail, distinct lines will remain, and lead to slivering of the rail head under traffic. It is found that the chemical composition of the rails remains practically unchanged, and the rolling which the metal receives at the comparatively low temperature actually improves the wearing qualities of the rail. The loss of metal from oxidation in heating and re-rolling amounts to about 1 per cent., and the entire loss from the rails, including the crop ends, amounts to $7\frac{1}{2}$ or 8 per cent. in weight of the metal rolled.*

Electric Power in Rolling-Mills.—O. Lasche † discusses the use of electricity in works and rolling-mills as a source of power, and gives instances of the application of electro-motors. The question of a central station for power production is first dealt with, and then that of driving by means of electromotors, this latter being dealt with in detail.

The results of some tests of heavy planing and other machines driven by electromotors have been published,‡ as supplied by Captain Tresid-

* *Iron and Coal Trades Review*, vol. lx. p. 301.

† *Stahl und Eisen*, vol. xix. pp. 905-913; 15 illustrations and 1 plate.

‡ *Engineer*, vol. lxxxix. pp. 304-306, with plate.

der from the Atlas Works, Sheffield, special autographic ammeter records being given.

Central Steam Condensing Plants for Ironworks are described by W. H. Roy.* The conditions under which they can be operated and the difficulties to be surmounted are discussed, together with the economies derived from their use. Typical plants in successful use are described with the aid of a number of illustrations.

Photography in Ironworks.—L. A. Osborne† deals with the methods of photographing the interior of works, and gives some notes on the most suitable forms of lens and camera, the choice of the point of view, and the methods of dealing with halation.

* *Journal of the West of Scotland Iron and Steel Institute*, vol. vii. pp. 19–42.

† *Mines and Minerals*, vol. xx. pp. 145–148.

PRODUCTION OF STEEL.

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I.—THE CARBURISATION OF MALLEABLE IRON.

Crucible Furnaces.—E. Schmatolla* observes that it is a well-known fact that the melting-furnaces used in foundries are, as a rule, not of modern type, and are occasionally of altogether primitive construction. With a few exceptions, they are not only unrational and uneconomical, but in many cases are also dangerous to the health of the workpeople. For a long time, the author observes, he has been engaged in endeavouring to perfect these furnaces, both as regards saving in fuel, labour, and crucibles, and also from a hygienic point of view. It must perforce be admitted, he points out, that any furnaces, such, for instance, as is usually the case with those which are termed "French," which are built immediately adjoining the shaft, and which allow the hot furnace gases to escape altogether unutilised, must be altogether irrational. From the point of view of avoiding changes in the practice to which the workmen are accustomed, the author has made the French type the basis of his experiments. How he has improved this form of crucible furnace is shown by a sketch. In this modified form the furnace gases first enter another chamber in which their combustion may be completed by the introduction of hot air. This leads to such a further increase in temperature that another crucible may be heated in this space, which becomes consequently a second furnace.

* *Stahl und Eisen*, vol. xix. pp. 1158-1160.

Instead of this extra-combustion chamber, the hot gases may be simply utilised to pre-heat the air required for the original furnace, in a way the author describes. In many cases it may be useful to allow the gases to pass into another chamber, which may be utilised for drying purposes, before they pass to the stack. How this can be arranged for is shown in the author's sketch. The use of cold blast often causes the crucible to suffer, but by pre-heating the air this is avoided. A considerable saving in fuel also results.

Illustrations have appeared * of the gas-fired crucible steel furnace designed by B. Dawson, S. Robinson, and S. Pope. A six-hole furnace of this type with six pots in each hole has been in successful use since August 1898 at the Brightside Works, Sheffield, and others are to be built.

II.—THE OPEN-HEARTH PROCESS.

Basic Open-Hearth Practice.—T. Turner † compares the basic and acid open-hearth processes of steel manufacture, and touches upon the application of Saniter's desulphurising process in connection with the basic process, of which he gives a general description with numerous analyses. The furnace lining is composed of calcined dolomite, and on the average contains :—

CaO.	MgO.	Al ₂ O ₃ .	Fe ₂ O ₃ .	SiO ₂ .
55-60	29-32	3-4	3-4	3-4

With care the hearth will last two years, but it is safer to renew it yearly.

Some average analyses of basic pig iron, from different sources, are as follows :—

	Stafford-shire.	York-shire.	East Coast.	Stafford-shire.	North Wales.	Belgium.
Carbon .	3·0	2·6	2·5	2·7 *	3·71	3·00
Phosphorus .	3·54	2·5	2·2	3·0	2·78	2·20
Silicon .	0·6	0·4	0·75	0·3	0·9	0·20
Sulphur .	0·05	0·05	0·06	0·06	0·035	0·04
Manganese		1·5	2·5	2·9	2·98	1·50

* *Iron and Coal Trades Review*, vol. lx. p. 251.

† *Journal of the West of Scotland Iron and Steel Institute*, vol. vii. pp. 121-139.

Cleveland white pig iron containing—

C.	P.	Si.	S.	Mn.
3·0	1·5	1·0	0·25	0·25

is to be used in an extensive plant of Messrs. Bell Bros., in connection with Saniter's process. Charging with molten iron is now largely used, and is considered to be a great advance. The Talbot process of continuous working is also referred to. In British basic practice the charge of an ordinary furnace may be, say, 70 to 80 per cent. of pig iron, and 30 to 20 of scrap, which may be of very mixed character, though it is preferable to have uniform material.

For quick working, plenty of carbon in the pig iron, in proportion to phosphorus, is desirable, as it enables the phosphorus to be got down low enough to tap by the time the carbon boil has disappeared, otherwise there is delay by the addition of grey pig iron for "pigging back," or, in other words, prolonging the boil, a further addition of lime being necessary to keep the slag basic.

The phosphorus combines with the lime in the slag and forms phosphate of lime, phosphoric acid being thus present in the slag, usually to the extent of 10 to 18 per cent. From a pig iron containing 3 to 3½ per cent. of phosphorus, the slag amounts to about one-fourth to one-third the weight of steel, and averages a content of about 15 per cent. of phosphoric acid. Three analyses of slags are here given:—

	No. 1.	No. 2.	No. 3.
	Per Cent.	Per Cent.	Per Cent.
Silica	10·5	13·00	14·80
Iron	7·61	11·23	10·33
Phosphoric acid	16·0	13·35	14·54
Lime	31·4	28·80	37·00

The calcined pottery mine of fair quality for oxidising would be as follows:—

Fe ₂ O ₃ .	FeO.	S.	Si.	MnO ₂ .	Al ₂ O ₃ .	P.
61·72	9·69	1·02	2·92	4·18	2·13	0·58

Other examples of oxidising materials are also given. The log of one charge is then given, and the use of various additions, such as silicon and aluminium, referred to.

For mild steels from phosphoric pig iron the following may be

given as the average quantities of materials consumed over a period of several months :—

	Per Ton of Ingots.
Basic pig iron	13½ cwt.
Grey pig iron	1½ „
Wrought scrap	6¾ „
Total	21½ cwt.
Spiegeleisen (20 per cent. Mn.)	5 lbs.
Ferro-manganese (80 per cent. Mn.)	5 „
Puddling mine	3½ cwt.
Limestone	4 „
Lime	½ „

From this consumption there would be obtained nearly three-fourths of a cwt. of ladle, pit, and lump scrap, in addition to the ton of ingots.

A long series of analyses and tensile tests of various classes of basic steels is appended.

Details are given * of a week's work in a 25-ton basic furnace, fired with producer-gas, at a steelworks in Illinois. Twenty-two heats were made in 137 hours; 54,300 lbs. of metal was charged, and steel with 0·13 carbon was made. The ore additions ranged from 700 to 1500 lbs. in each heat.

The Wellman Charging Machine.—Some illustrations of the Wellman charging machine, adopted by Vickers Sons & Maxim at Sheffield, have appeared.† Three 25 horse-power electromotors are used respectively to traverse the machine along the row of furnaces, to work the charging truck and the charging bar, and a fourth motor of 3½ horse-power rotates the charging bar to turn over the box containing the charge. The machine serves three furnaces, but is capable of serving six. The controllers are of the Dinkey type, with resistances of flat metallic tape.

Illustrations are given ‡ of the controllers or switches for controlling the electromotors used in the Wellman charging machine.

The Talbot Process.—Some notes on the Talbot process, which is described in a paper in the present volume, have been published.§

* *Iron Age*, March 22, 1900, p. 16.

† *Engineer*, vol. lxxxix. pp. 273-274, 282.

‡ *Iron Age*, March 22, 1900, p. 13.

§ *Ibid.*, February 8, 1900, pp. 5-7; *Iron and Coal Trades Review*, vol. ix. pp. 354, 355.

The Bertrand-Thiel Process.—J. Hartshorne * gives some further notes on the Bertrand-Thiel open-hearth process, with tabulated results of the work done in two runs in June and December of 1899. The average composition of the metal from the blast-furnace and from the primary furnace was as follows:—

	C.	P.	Si.	Mn.
Blast-furnace . .	3·5	1·5	1·0	0·4
Primary furnace. .	2·4	0·1 to 0·2	trace	trace

During the first week of December there were 48 heats, with a production of 730·67 metric tons of ingots. The ore charged weighed 184·56 metric tons and limestone 70·2 tons. The metal charged included:—

	Kilogrammes.
Pig iron, liquid	571,190
Pig iron, cold	73,390
Old rolls	16,290
Scrap	55,280
Spiegeleisen	8,480
Ferromanganese	10,400
Metallic charge	735,030
Ingots produced	730,670
Loss in ingots	4,360

The weight lost in the ingots was 0·6 per cent., but as the metal lost 6·4 per cent., there must have been 8·25 per cent. of iron reduced from the ore to make up for the amount, or even more, if the shot in the slag, &c., be taken into account. The average for the month of December is given as 1·02 ton of total product for every ton charged, and in ingot product of 98·82 per cent. 81·6 metric tons of slag, with 20 to 23 per cent. of phosphoric acid, was produced.

New American Steelworks.—Illustrations have appeared † of the steelworks at Ensley, Alabama, where there are ten 50-ton furnaces erected in a line in a building 736 feet by 80 feet. Thirty-two gas-producers are fed with coal from an overhead line carrying full-sized railway trucks. The furnaces are charged by two Wellman machines, and the metal is poured into ladles carried by 40-ton cranes. The blooming-mill is 44 inches in diameter, operated by a 1500 horse-power reversing engine, with 36 by 48-inch cylinders.

* *Transactions of the American Institute of Mining Engineers*, Washington meeting.

† *Engineer*, vol. lxxxix. pp. 142-143.

In a paper read before the *Eisenhütte Oberschlesien, Stammschutte* * refers to various improvements introduced of late years into American steelworks. He points out that casting-pits have been almost entirely abandoned, and are replaced by another method of casting, in which the ingot moulds are carried on narrow-gauge waggons, two to four on each. Several works using this method are referred to, and the arrangements employed described. Some new steelworks are also described and illustrated.

III.—*THE BESSEMER PROCESS.*

Small Converters.—E. F. Lange † discusses at some length the scope of the small converter in steel-foundry practice. The early forms of Bessemer's converters, fixed and movable, are first referred to, and to them are ascribed the origin of the modern fixed converter; but the modern tilting side-blown converters are not the outcome of his early forms, but are an evolution of the modern fixed converter. At the beginning of the eighties a number of converters, designed by Clapp & Griffiths and Witherow in America and Hutton in this country, promised many advantages, producing fine steel, but with great waste of iron. The chief features of these forms are briefly mentioned, and the advantages and disadvantages of the type are set forth. One of the Clapp-Griffiths converters was erected in Paris, and led to the design of the Walrand-Delattre tilting converter, with the tuyeres on one side. Robert altered this form by flattening the tuyere side and making other variations. Then Tropenas, with the experience gained with these forms, designed his converter at the works of Edgar Allen & Co., and this system is now the one that is most extensively employed. The claims made by Robert and others for the side-blowing method, and its supposed advantages of not intermingling the slag and metal, are discussed, and also the introduction of the upper tuyeres in the Tropenas vessel for burning the carbonic oxide above the bath. Next reference is made to the Walrand-Légénisiel method of insuring heat at the end of the blow by introducing ferro-silicon after the decarburising period, and then making an after-blow. At a Paris works this method was carried on as follows:—305 kilogrammes of molten mixed

* *Stahl und Eisen*, vol. xx. pp. 357-364; 8 illustrations.

† Paper read before the Sheffield Society of Engineers and Metallurgists, March 26, 1900.

pig iron was charged from a cupola, blown, and 20 kilogrammes of 10 per cent. ferro-silicon added after the boil. The after-blow lasted two and a half minutes, and 12 kilogrammes of ferro-manganese were added. A slight blow mixed the bath; then 0.05 per cent. of aluminium was added, and the steel poured. No skull was made in the ladle, and two successive blows might be teemed into the same ladle. The spectro-scope is used in determining the various stages of the process. The chemistry of the side and bottom-blowing processes is then considered again in greater detail, and it is pointed out that Robert and others neglect the effect of the admixture of the oxide of iron with the metal. It is possible that side-blowing may give a better resultant metal, but the reason is not clear; but bottom-blowing is more economical as regards waste by oxidation of the iron. The relative costs of the two systems is shortly considered, and then attention is turned to the use of small converter metal as a substitute for malleable iron in castings. At Charleroi, in Belgium, one of the largest makers of malleable castings has replaced his plant by converters, and elsewhere small steel castings have been made with much success, in spite of the higher cost of some parts of the procedure. It has been stated that it is only conservatism which prevents the replacement of malleable by steel castings. The use of scrap offers several problems for solution, as much cannot be used unless an excess of coke is employed for melting, or otherwise the heat is cold. A great point in favour of small converters is the readiness with which they can be thrown in and out of work, and their general adaptability to all classes of work, while a small open-hearth must have at least 4 tons capacity. The drawback is the waste of iron, which may amount to 25 per cent. or more, and the uncertainty as to the quality of the product. For castings or forgings for responsible work, only the open-hearth is suitable, but for all small castings, where the tensile and other requirements are not of the first importance, the small converter is certainly well adapted, so that it may be employed as an accessory, and not as a substitute.

C. Rott * also deals with the small converter methods from a German point of view, and thinks that it has a great future for the manufacture of direct castings. He observes that in the Robert method, which is the one most commonly in use in France, a side blast is employed. In the Tropenas converter, on the other hand, the blast is directed on the surface of the bath of metal. Walrand's converter only differs in size from an ordinary Bessemer converter. The pin-hole bottom is re-

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlv. pp. 144-149; 19 illustrations.

tained in this form of small converter. The charge is from 8 to 16 cwt. In each of the two other small converters just mentioned the minimum charge is not less than about a ton. Two three-quarter ton Walrand-Légénisel converters were erected by the Hagen Steelworks in 1890, and another small Bessemer plant was erected at Halle on the Saale in 1896. Of this plant the author became the manager, and he now describes it. The charge was about $5\frac{1}{2}$ cwt. This consisted of German hæmatite pig iron containing

Carbon.	Silicon.	Manganese.	Phosphorus.
3·5	2·3	0·8	0·07

with an addition of about 10 per cent. of scrap from former casts melted down with 8 per cent. of coke. The converter is pre-heated by a wood and coke fire. The way the blow proceeds is described, and curves are given showing the order in which the various elements are eliminated from the iron. The German method shows that, starting with the charge at a high temperature, the carbon gradually diminishes as the process proceeds. When a temperature of 1400° C. is attained, the combustion of the silicon ceases, as then the carbon is first to burn. Only when the carbon disappears does the silicon begin to oxidise out again, but about 0·29 per cent. still remains in the metal. The recarburisation with ferro-manganese and the high temperature at the commencement of the operation are stated to be typical of the German process. In the British process pig irons are used which are high in manganese and silicon, and which consequently admit of a low initial temperature for the blow. It is almost exclusively the silicon which burns at first, the percentage of carbon actually increasing during the first six minutes of the blow. This element only begins to oxidise when a temperature of 1500° C. is reached, but oxidation proceeds so rapidly that in the course of the next twelve minutes the high percentage of 3·75 to 4·0 has almost quite disappeared. The silicon is the heat-producing agent, and the addition of spiegeleisen slightly increases the percentage of carbon and manganese.

In the Swedish method the percentage of silicon is only just high enough to bring the iron up to a temperature of 1500° , even though it is very hot to commence with. In the first period the manganese and silicon burn out, and the percentage of carbon increases. The blow then proceeds very rapidly, and when the desired composition is reached the blow is simply stopped, there being no recarburisation employed. Unless the temperature of the metal was high to start

with, it would not be possible to blow a metal low in silicon. That used is shown as containing

Carbon.	Manganese.	Silicon.
3.94	0.63	1.14

The author devotes special attention to the German method with acid linings. Four mixtures are given for producing the moulds in which the steel made should be cast, as well as the moulds themselves. The experience obtained at the Halle works strengthens the opinion that the small Bessemer plant is of great importance in steel-foundries. The author considers the way in which the blast should be directed on the metal, and amongst other points gives some details as to the cost of the process. In the case referred to, five charges of 0.35 ton were blown in one day, a total of 1.75 ton, which yielded approximately castings weighing 0.8 ton. The total wages were 18.50 shillings, and the cost of materials of all kinds 22.35 shillings, or 40.85 shillings in all. This includes depreciation and costs of all kinds. The products sold at about £30 per ton, and even more. The author considers that the Bessemer process on a small scale has a favourable future before it. It will not compete with the open-hearth for large castings, but where there is a market for small-sized castings, then this small Bessemer plant will be found useful.

In commenting on this account, R. Moldenke * does not think this method will find much field in the United States.

A plan has appeared † of a cast iron and steel foundry recently erected in Chicago. Three 2-ton Tropenas converters and two cupolas, one 60-inch and one 72-inch, are installed.

A short description ‡ has also appeared of a steel-foundry with a capacity of 80 tons daily, to be erected at East Pittsburg.

The Duplex Process.—Discussing the paper by Sattmann on the use of a very high percentage of iron ore in the open-hearth process, R. M. Daelen § disputes the advantages claimed, and contends :—(1) That the production of pig iron for conversion into ingot metal is cheapest when the attainment of a certain definite chemical composition has not to be striven for ; (2) That a preliminary treatment with an air blast necessitates a second source of heat if the pig iron under

* *Iron Trades Review*, March 22, 1900, p. 11.

† *Iron Age*, November 9, 1899, pp. 8-9.

‡ *Ibid.*, November 16, 1899, p. 10.

§ *Stahl und Eisen*, vol. xix. pp. 1173-1175.

treatment does not itself contain sufficient fuel for that purpose, and that hot blast for the blast-furnaces is the cheapest to employ; (3) That this preliminary treatment is best effected in a converter of simple form placed by the blast-furnace; and (4) That the open-hearth process attains its cheapest form when the bath, after the iron that is charged in has been subjected to a previous oxidation, has the composition which it now has in the ordinary pig iron and scrap process after the melting down of a charge. He also points out that it is far from advisable to make any changes in the shape of the furnaces used that are based merely on supposition. It is possible, the author adds, by the duplex converter open-hearth process, to treat successfully a pig iron containing as low a percentage of carbon and of silicon as is ever obtained in ordinary blast-furnace practice. To this Sattmann * replies.

The Utilisation of Basic Slag.—A description is published † of the way in which basic Bessemer slag and phosphates are converted into marketable products. The first process consists in grinding them to an adequate degree of fineness. The Löhnert mill has not proved satisfactory for grinding slag, and nothing more is now heard in Germany of the Cyclone pulveriser as used for this purpose, nor of Wood's mill. The French mill with horizontal stones, the ball-mill, and the Griffin mill are masters of the situation. The latter mill especially appears to give satisfaction. The price, however, is high, and this has led to older methods being frequently retained. A combination is common which consists of a rock-breaker which brings the slag to nut size, then the ball-mill and sieves, and then the French mill to complete the grinding.

E. Grandeau ‡ discusses the value of the slags obtained in the basic process of steel-making. For four tons of basic steel made a ton of slag is obtained, and of this slag last year Europe produced 1,416,000 tons. France consumed its entire output—198,000 tons—for agricultural purposes. It is a curious fact that of this 198,000 tons half was exported to Germany and re-imported at the cost of a double transport.

The Imperial Japanese Steelworks.—Notwithstanding the plentiful occurrence of iron ore in Japan and the considerable lapse

* *Stahl und Eisen*, vol. xix. pp. 1175-1177.

† *Chemiker Zeitung*, vol. xxiv. pp. 8-9.

‡ *Le Temps*, March 3, 1900.

of time since the first ironworks was erected there in 1875 by David Forbes, Foreign Secretary of the Iron and Steel Institute, the far greater proportion of the iron and steel consumed is still imported. Recently, however, it was decided to erect a steelworks, at the expense of the State, at Yawatamura, on the shores of the harbour of Wakamatsu (Fukuoka), about ten miles from Shimonoseki, the site of the works covering an area of over 200 acres. The harbour near the quay has been deepened by dredging, so that there is about 20 feet of water at low tide. Water is laid on to the works through a main from the river Itabit, which is able to supply 660 gallons per minute when at its lowest, and double that quantity when full; and there are also a couple of reservoirs on the premises. The loading place is connected with all parts of the works and also with the Kiushu Railway, the total length of line at present being about ten miles, to which will be added a further length of four miles by the time the works are completed.

According to E. Schrödter* installations for the supply of power by steam, electricity, and hydraulics are provided, the waste gases from the blast-furnaces and coke-ovens being utilised for generating the whole of the steam, except in the locomotives. Altogether there are fifty-two boilers, with a total efficiency of about 10,000 horse-power, twenty-four steam-engines capable of developing an aggregate of 31,200 horse-power, a 1500 horse-power electric plant, and a 200 horse-power hydraulic plant.

A portion only of the crude iron treated is of native origin, it being proposed to deal with Japanese magnetite—containing 60 per cent. of iron, with but a small proportion of phosphorus—from Kamaishi, about 1000 nautical miles distant from the works; together with phosphorus-free hæmatite from Akadani (450 miles away), and from Sennin (870 miles off); and Chinese magnetite and limonite from Tajeh and Hupeh (1100 miles distant). The coal is won in the neighbourhood of the works, and is said to furnish good coke; it will be treated in a washing plant capable of dealing with about 1200 tons per twenty-four hours, whilst 200 coke-ovens, with mechanical dischargers and twenty-eight boilers, are provided for coking. The plan of the works was prepared by F. W. Lürmann of Osnabrück.

At the front and rear of the blast-furnaces are two standard gauge tracks for removing the molten iron and slag, and in the rear are the electric charging lifts, behind which again are two narrow-gauge tracks

* *Stahl und Eisen*, vol. xix. pp. 1141-1151.

for the coke waggons. Then follow two sets of roasting kilns, of the modified Westmann type, 34 feet high, heated by gas and dealing with 40 tons of ore per twenty-four hours day. Parallel to these furnaces are storages, over which, at a height of 26 feet, run three sets of normal gauge tracks, on to which the trucks laden with limestone and ore are pushed by engines up an incline (1 in 45) and then discharged.

Two blast-furnaces are being erected first. These are about 75 feet high, and capable of producing 165 tons per diem (twenty-four hours). The blast-engine house, 73 yards long by 24 yards wide, contains four compound horizontal engines, with the following dimensions:—Diameter of high-pressure cylinder, $35\frac{1}{2}$ inches; of low-pressure cylinder, 51 inches; of the air-cylinders, 75 inches; common stroke, 60 inches; speed, thirty-four revolutions per minute; total air supply, 18,100 cubic feet per minute; pressure, 0·7 atmosphere; total indicated horse-power of the engines, 850; consumption of steam, $17\frac{3}{4}$ lbs. per horse-power hour. A 10-ton crane is also provided. The eight hot-blast stoves are of the Cowper type, each being 98 feet high and 20 feet in diameter; the gas conduit is 80 inches wide and 765 yards long, the hot-air pipe being 60 inches outside diameter and 207 yards long, and the cold-air pipe 40 inches wide and 175 yards long. There are twenty-four boilers, each measuring 88 inches in diameter and 36 feet in length, with two 32-inch tubes, the heating surface being 1038 square feet and the steam pressure $8\frac{1}{2}$ atmospheres.

The casting-house consists of two iron sheds 130 feet long by 65 feet wide, containing two casting-ladles. The condensing plant consists of an enclosed twin surface condenser capable of treating 1034 lbs. of steam per minute, together with a pair of electric air pumps, and electric condensed water pump and a wooden cooling tower for sea-water.

Between the blast-furnaces and the steelworks are two 160-ton mixers tipped by hydraulic power, and two 200-ton cupola furnaces. The converter-house is fitted with two converters of the American type, 19 feet high, 10 feet wide, and with a capacity of 400 tons each per twenty-four hours. The horizontal compound blower engine for the Bessemer works measures: Diameter of the high-pressure cylinder, 7·8 inches; of the low-pressure cylinder, 67 inches, and of the air cylinders, 63 inches; stroke, 59 inches; volume of air dealt with per minute, 14,126 cubic feet; pressure, 2·2 atmospheres; indicated horse-power, 1600; consumption of steam, 17·6 lbs. per horse-power hour.

There are also two cupola furnaces for spiegeleisen, a 20-ton electric

travelling crane, three 15-ton casting-pots, &c. Four 25-ton open-hearth furnaces are also projected, the hearths measuring 20 feet long by 9 feet wide, the total length of the furnaces being 41 feet, width $21\frac{1}{2}$ feet, and height $28\frac{1}{2}$ feet. Each furnace is expected to produce 50 tons in twenty-four hours. There are twelve bottom-draught producers, a Wellman electric charging apparatus, a 50-ton electric casting crane, two 30-ton casting-pots, &c., and a workshop fitted with ten cold saws, sundry lathes, drying chambers, warming ovens, &c.

The rolling-mills comprise a heating-furnace house 65 feet long and 39 feet wide, fitted with seven furnaces heated by producer-gas, hydraulic opening and closing appliances, and a 3-ton electric crane. The rolling-house, 223 feet long and 65 feet wide, contains a rolling-mill, with rollers 9 feet long by $3\frac{1}{2}$ feet in diameter, driven by a 4000 horse-power horizontal double-cylinder engine; there are also a 25-ton and a 10-ton crane, with a steam hydraulic shearing machine for dealing with red-hot ingots up to 12 inches side. The rail-mill is driven by a 500 horse-power triple-cylinder horizontal engine, and in this building are also an electric hot-shearing machine, four electric trueing machines, sixteen electric borers, and a 10-ton crane. Roughing and finishing rolling-mills for bar and sheet metal are also projected.

The central pumping station contains two air pumps, two condensed water pumps, two pumps for the blast-furnace condensing plant, and two for the hydraulic accumulators, supplying 220 gallons per minute at 50 atmospheres pressure. Two other accumulators, a Linde refrigerator, and a condenser are also provided, together with a water main 380 yards long and a drain 317 yards in length. The central electrical station is fitted with two 250 volt 380 kilowatt continuous-current dynamos, a small dynamo (250 volts, 166 kilowatts), 120 accumulators, a switch-board, and three steam-engines. Other branches of the works include a repairing shop with electric machinery, a casting foundry, moulding and modelling shops, smithies, laboratories, &c., and two $1\frac{1}{2}$ -ton portable cranes for loading, a 24-ton quay crane, and a 10-ton mast crane worked by hand.

The anticipated yearly output amounts to 35,000 tons of rails and 10,000 tons of rods from the Bessemer works, and 25,000 tons of sheet metal, 15,000 tons of castings, and 5000 tons of rods from the open-hearth furnaces, a grand total of 90,000 tons.

A number of views of the Japanese Imperial Steelworks are given by E. Schrödter.*

* *Iron and Coal Trades Review*, vol. 1x. pp. 213-215.

FURTHER TREATMENT OF IRON AND STEEL.

Methods of Case-Hardening.—According to John Buckley,* the process of case-hardening has not changed materially for the past few years. The principal materials used remain the same: Granulated raw-bone, hydrocarbonised bone-black, black oxide of magnesia, soda, charcoal, and salt.

The work to be hardened is packed in cast or wrought iron boxes, sealed with fireclay or mud. The pieces to be hardened should be placed about two inches apart in the box and the vacant spaces well filled with the material. With heavy work fifteen to twenty hours of steady heat is necessary in order to secure best results; light pieces take eight to ten hours.

Furnaces for case-hardening should be so constructed that the boxes will not have to be raised or lowered while being put into or taken from the furnace. The heating space is near the ground. The fire-box and ash-pan are below the surface. This refers to a furnace heated with soft coal. A chimney about 16 feet high will furnish draught enough to heat the boxes without aid of a blast. Case-hardening furnaces which are heated with fuel oil are of a very different construction, the boxes being generally heated from the top; with coal, in most cases, it is from the bottom. The cooling tub is arranged so as to admit cold water from the end near the bottom, the cold stream thus running lengthwise along the bottom of the tub.

H. F. Hinkens† gives the percentages of carbon that render steel suitable for various tools, and adds some remarks on the treatment of the metal by the blacksmith.

Some notes on the methods of obtaining the best results in the

* Paper read before the National Railroad Master-Blacksmiths' Association.

† Paper read before the North-West Railway Club; *Iron Trade Review*, November 9, 1899, p. 11.

manipulation of high carbon steel have been given by M. B. Messimer and E. F. Carter in the Report of the Committee appointed by the National Railroad Master-Blacksmiths' Association.*

The Manufacture of Steel Castings.—J. E. Fletcher † describes the manufacture of steel castings, of which the chief difficulty is in connection with their contraction. The contractional co-efficient being, roughly, double that of cast iron, very special means are necessary in order to release castings of larger dimensions rapidly and successfully whilst cooling. The author then examines the design of characteristic castings for hydraulic machinery, engines and boilers, millwork and electrical machinery, pointing out where difficulties in manufacture occurred, and suggesting how such troubles might be overcome, his remarks being illustrated by a number of diagrams.

Reheating Furnace.—In the heating furnace for plates, &c., designed by F. E. Ross, the heating chamber is divided by brickwork partitions into compartments, each of which holds one or two pieces of the work. The brickwork stores the heat and gives several other advantages. ‡

Wire Manufacture.—A plan of the Bedson wireworks at Middlesbrough and a number of views of the machinery have been published.§

J. D. Brunton || describes the various methods of wire manufacture from wire rod. The initial pickling is of the very greatest importance, and no efficient substitute for the acid bath has been discovered for cleaning the wire. The various processes of pickling, coating, drying, and liming the wire, the preparation of the dies, the different methods of annealing the wire and galvanising it are described in some detail.

Steel Waggon.—Illustrations are given ¶ of a number of types of steel underframes, and steel railway waggon of from ten to thirty tons capacity.

* *Industries and Iron*, vol. xxvii. p. 284.

† Paper read before the Manchester Association of Engineers, November 11, 1899.

‡ *Iron and Coal Trades Review*, vol. lix. pp. 1091-1092.

§ *Ibid.*, vol. lix. pp. 1133-1136.

|| *Journal of the West of Scotland Iron and Steel Institute*, vol. vii. pp. 91-96, 116-120.

¶ *Iron and Coal Trades Review*, vol. lix. pp. 993-996.

The Manufacture of Structural Steel.—F. H. Kindl * discusses various points in the manufacture of steel for building construction, and urges the necessity for the use of standard sizes and specifications in order to ensure early delivery. The constant changing of heavy rolls, which has to be done when different sizes are rolled, consumes much time and labour, and is accordingly expensive.

F. H. Kindl † gives a general account of the manufacture of structural steel in the United States, with illustrations drawn from the South Chicago and other works. These include the blast-furnace plant and casting-house, the electric handling appliances for beams, the 35-inch rolling-mill and tables, a slabbing-mill, spiegeleisen cupola, charging floor, metal mixer, rolling open-hearth steel-furnaces, soaking pits, charging bloom-furnaces, hot-blast stoves, straightening and cooling tables, merchant mill, plate-shearing machines, 48-inch mill and engine, and a rail-mill.

Tubes.—Illustrations have appeared ‡ of a machine for drawing seamless steel tubes with longitudinal ribs, the tube sections being round or rectangular with external ribs. At Duisberg on the Rhine, where these tubes are used, they are drawn from flattened hollow ingots of open-hearth steel, having a breaking strength of 57,000 to 71,000 lbs., and an elongation of 20 to 30 per cent.

The Manufacture of Screw Shapes.—Haedicke § considers the various methods that are employed for screw shapes of different kinds. Corkscrews are still chiefly made by a smithing process. Stamping presses are largely employed, generally on a manufacturing scale, and various forms of these are described.

Armour.—In a recently published memorandum, Admiral O'Neil, || chief of the United States Bureau of Naval Ordnance, discusses the Harvey and Krupp processes of armour-making in favour of the former.

The manufacture of armour plates at the Cyclops Works, Sheffield, is described, with the aid of illustrations showing the bending press, electric crane, armour plate-mills, steel casting plant, and some of the machinery. ¶

* Paper read at the thirty-third Annual Convention of the American Institute of Architects at Pittsburg.

† *Cassier's Magazine*, vol. xvii. pp. 259-278.

‡ *Iron and Coal Trades Review*, vol. lx. p. 552.

§ *Stahl und Eisen*, vol. xx. pp. 365-368; 24 illustrations.

|| *Industries and Iron*, vol. xxviii. p. 7.

¶ *Iron and Coal Trades Review*, vol. lix. pp. 1087-1090.

1900.—i.

The requirements of different nations as to the mechanical tests to which armour plates are to be submitted are discussed by L. Baclé.* The subject is dealt with in some detail in an interesting memoir showing the progress that has been made in armour plate manufacture during the last twenty years. Thus it has been found that an armour plate 7·87 inches in thickness, when attacked by a 7·6-inch gun, requires for penetration the relative velocities shown below :—

	Perforation Velocity. Metres.
Puddled iron	385
Ordinary steel	471
Special chrome-nickel steel	528
Cemented	612

Armour plate manufacture in Germany is discussed.†

The idea of using armoured trains is by no means new,‡ and illustrations are given of some of the older of such armoured trains. The first illustrated was one used in the war between the Northern and Southern United States in 1861 to protect the Philadelphia, Wilmington, and Baltimore Railway. The second was one used in the rebellion in Egypt under Arabi Pacha in 1882. Other similar trains were in use in the late Revolution in Chili. One of the other illustrations refers to a train that was employed in the war between the United States and Spain to protect the line of railway between Colon and Santa Clara. The third illustration is that of such a train employed in the present war in South Africa.

The Manufacture of Guns.—Illustrations have appeared showing the gunshop at the Government Factory at Washington, and a general description of the manufacture of built-up guns is given.§

Making Rifle Barrels.—E. G. Parkhurst|| gives the number of operations on a military rifle barrel as thirty-two, and these are briefly described with the aid of illustrations.

Some interesting figures are given in a recent report on the effect of machinery on cost of production, issued by the American Department of Labour. This report expresses in concrete figures the measure of

* *Mémoires de la Société d'Encouragement pour l'Industrie Nationale*, 1899, pp. 1652-1803.

† *Engineer*, vol. lxxxix. pp. 387-388.

‡ *Stahl und Eisen*, vol. xix. p. 1186; 3 illustrations.

§ *Marine Review*; *Iron Trade Review*, October 5, 1899, pp. 12-14.

|| *American Machinist*, vol. xxiii. pp. 387-393.

advantage that has accrued in various industries from the adoption of machinery, and thus permits of instructive comparison. It includes statistics relating to about ninety main industries, and gives tabulated results of nearly 700 branches that have been investigated. The labour necessary, for instance, to produce a file has been reduced one-third, while a rifle barrel, which occupied about 98 hours of hand-labour in 1857, is now produced with a total of $3\frac{2}{3}$ hours to-day. In 1835 it took $84\frac{1}{2}$ hours of hand-labour to produce 100 feet of lap-welded tube, a quantity which was turned out in 1895 in less than five hours. Fifty years ago, 500 half-inch bolts with nuts took 43 hours to complete, whereas modern machinery can turn out the same quantity in eight hours. At the beginning of the century it took about 130 hours of heavy labour to produce a quantity of nails which can now be turned out in one hour.*

Ornamental Ironwork.—An exhibition of chased and embossed steel and iron work of European origin has been held at the Burlington Fine Arts Club, and the catalogue,† prepared by J. Starkie Gardner, contains much information on the subject. The fact that this collection is the first of the kind brought together invests it with unusual interest.

Galvanising.—S. Cowper-Coles ‡ again describes the methods of the apparatus for galvanising, especially the electric methods.

Enamelled Iron.—A plan of a new enamelled iron-ware factory has appeared.§ It contains space for pickling, nickel plating, dipping, and drying the ware, and twenty muffles for firing it.

Eye Accidents in Iron and Steel Works.—S. Snell|| in an address delivered at the opening of the section of Ophthalmology at the meeting of the British Medical Association at Portsmouth, August 1899, deals with the prevention of eye accidents occurring in trades, especially from dust or chips made in grinding or chipping, and splashes of molten metal. The cleanliness of instruments used for removing the motes and the use of guards of wire gauze are insisted upon.

* The report is published in serial form in *Engineering*, vol. lxi.

† A copy has been presented to the Institute Library by the Burlington Fine Arts Club.

‡ Paper read before the Cleveland Institution of Engineers, April 1900.

§ *Iron Age*, February 15, 1900, pp. 10–11.

|| Pamphlet, pp. 32. Reprinted from the *British Medical Journal*. A copy is in the Library of the Iron and Steel Institute.

PHYSICAL PROPERTIES.

The Micro-Structure of Iron.—J. E. Stead * deals with the method of preparing metals and alloys for microscopic examination, cutting, grinding, polishing, and etching samples of metal, and shows that the essential constituent parts were gathered into separate and easily distinguishable centres. The carbides are also shown to be in isolated silver crystals, while the phosphorus and sulphur compounds are seen each distinctly separated from the other constituents. It is demonstrated that if a piece of white pig iron, containing carbon, sulphur, and phosphorus, is polished brightly, so as to have a mirror-like surface, and then heated until it became purple in colour to the naked eye, when examined under the microscope, it is seen that the various constituents are diversely coloured, the iron being a fine sky-blue, the carbides an orange colour, the phosphides a pale lemon yellow, and the sulphides a slaty blue. That phosphides could be identified in that way was an entirely new discovery. Hitberto, practical iron manufacturers had had a difficulty in telling whether pig iron contained phosphorus—it was impossible to tell from a fracture whether it was present or not. But by the simple process of polishing a chip of the iron as described and examining it under the microscope, they can tell at once whether phosphorus was present. A point of great importance to manufacturers was that by this process metallurgists were enabled to say at once, in very many cases at least, whether or not steel had been badly treated after it left their works. Frequently manufacturers have steel returned because it was alleged by the users that it was not up to the standard. By examining a specimen under the microscope, they could readily ascertain whether the steel had been improperly treated by the users, and so settle any dispute as to the quality of the material supplied by them.

* *Proceedings of the Cleveland Institution of Engineers*, 1900, pp. 97-137.

Owing to new developments in the research, the author has postponed his promised paper on these matters until the Paris meeting of the Institute, but a note on them will be found in the present volume.

F. Osmond * and G. Cartaud have found that a 2 per cent. solution of ammonium nitrate in water yields good results in place of liquorice root for the etching and polishing of microscopic samples of steel. By its aid pearlite, troostite, martensite, and ferrite may be distinguished. Austenite and cementite are unaffected, but may be distinguished by electrolysis in an ammonium chloride bath.

J. A. Ewing † and W. Rosenhain have continued their microscopic investigations on the crystalline structure of metals, and consider that their experiments prove that the plasticity of metals is due to the sliding over one another of the crystalline elements composing each grain, without change in their orientation within each grain, except in so far as such change may occur through twinning. Various samples of iron and steel were examined in addition to other metals.

Other materials than metals show similar surface markings produced by stress. Thus clay cylinders under compression show hair cracks like those on a metal test-piece, and stretched paper shows a network of lines. Ewing and Rosenhain's experiments, in which they microscopically investigated specimens under tension, have shown that not only do the crystalline elements move in relation to each other, but also that the individual parts of the crystalline forms move and break up into a smaller crystalline structure. The movement is not continuous but periodic, and seems to be identical under tension and under compression. ‡

E. Heyn § discusses the present position of metallography. Referring, in the first instance, to alloys, he points out that, important though these are, and numerous as have been the investigations connected with their composition and properties, it is only of late that attention has been devoted to the question of their internal structure, and in what way this is connected with the properties of alloys and their constituents. Most people probably believe that, apart from occasional evident liquation products, alloys are homogeneous bodies, possessing identically the same chemical composition and physical properties throughout their whole mass. Such alloys form, however, the exception, and not the

* *The Metallographist*, vol. iii. pp. 1-3.

† Bakerian Lecture before the Royal Society.

‡ *Baumaterialienkunde*, 1900, p. 24.

§ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlv. pp. 137-144, 175-180, with 41 illustrations.

rule. Metallurgists, and above all Ledebur, have long insisted that alloys are to be looked upon as solidified solutions, and the microscope has shown this view to be correct. The term "metallography" is applied to the study of these metallic solutions. Naturally it must also deal with pure metals, as these play the parts either of solution agent or of dissolved substance. The use of the microscope in this connection is all-important, as the author shows, but it is not itself sufficient. Chemical analysis is a necessity, and also the various methods of general physical examination. When the number, characteristics, and percentages of the various constituents are ascertained, as well as their chemico-physical nature, then there comes another point, and that is the question as to how far they influence the properties of the alloy considered as a whole, and its behaviour generally.

The author first deals with the behaviour of metallic solutions when they solidify, and then considers generally the methods for the microscopic investigation of metals. The methods of preparation of the surface of the metal are fully dealt with. The author next directs his attention to the alloys of iron and carbon, which, he says, are the alloys that have received most attention up to the present time, the work of Osmond being specially referred to. In tabular form are given the more important micrographic reactions of the various constituents of iron-carbon alloys, while in another are shown the way in which they occur and are associated with each other, numerous illustrations being given in explanation.

After dealing with the observations made by aid of the microscope in these alloys, the next point considered is the deductions that are to be drawn from the observations made when such alloys, after having been heated to a high temperature, are allowed to cool. Osmond and Roberts-Austen, the author points out, were the first to deal with this matter thoroughly, and the author refers at length to the results obtained by these experimenters. Other alloys are also subsequently dealt with, and a partial bibliography is given of the subject.

M. Levitzky * observed certain white markings in tubes and cylinders made of steel from the Oboukhov Steelworks, and submitted them to microscopic examination. When the surface of polished steel is examined with the microscope, it is always seen that there is a want of homogeneity. Capricious designs can be noticed in every case. This is the result of intermolecular movement, which takes place at various stages in the manufacture of the metal, and the degree

* *Revue Universelle des Mines*, vol. xlix. pp. 65-82; 10 illustrations.

of which is largely dependent on the chemical composition of the steel, and on the temperature charge and mechanical treatment to which it had been subjected. There are four different kinds of material which are always observable in steel: ferrite, pearlite, cementite, and martensite. These the author describes and illustrates. Mechanical treatment is apt to produce certain bands of peculiar structure. Tchernoff has shown that they occur between those portions of the metal which have been reheated and those which have remained cold. If this intermediary zone is reheated these bands disappear. There are, however, some markings which can neither be affected by slow reheating nor by rapid reheating. Hammering modifies the direction and form of their sinuosities, but does not destroy them. It is not, therefore, a kind of damascening. In practice it is necessary in steel manufacture to make use of other elements besides iron and carbon, such, for instance, as manganese, silicon, nickel, chromium, tungsten, boron, &c. The metal then obtained is no longer iron or steel, but an alloy of iron with various other elements. In solidifying, these alloys, which are usually unstable, again split up, forming new alloys and causing liquation phenomena which give rise to marbling or the formation of capricious designs in the steels. These the author describes, especially certain striations of bright colour noticed in tubes and cylinders made of steel from the Oboukhov Works. Reheating did not destroy them. Analysis showed the metal in these streaks to be far higher in carbon than the rest of the metal. Thus, while the main mass of the metal contained 0.36 per cent. of carbon in one case, that in the streaks contained 0.68 per cent. The author draws various deductions as to how these streaks might be avoided and as to how they may have originated.

The Texture of Pig Iron—K. Glinz* discusses the question of the possibility of judging the character of a pig iron by an examination of its micro-structure. He describes an examination of a charcoal pig iron used for chilled castings, and a comparison of this with two samples of coke pig iron. The charcoal iron had the following percentage composition:—

	Total				
Graphite.	Carbon.	Si.	Mn.	P.	S.
3.17	3.42	2.76	0.77	0.935	0.02

In addition it contained 0.06 per cent. of nickel and 0.01 of copper. It will be observed that, as a consequence of the high percentage of

* *Stahl und Eisen*, vol. xix. pp. 1061–1063; 6 illustrations.

silicon present, 90 per cent. of the total carbon was in the form of graphite. The high silicon shows that the metal could only be used as an addition when making chilled castings. The manganese, too, exceeds the percentage usually employed when metal is to be used for the above purpose, and so, too, do the percentages of sulphur and phosphorus. The mechanical tests of this metal were, however, very satisfactory, as the author shows. It possessed great crushing strength and a relatively high degree of elasticity. For the purpose of subsequent microscopic examination three bars were cast, one in very dry sand, one in wet sand, and one in a chill mould. The texture of the metal cast in the damp sand was much larger than that of the metal cast in dry sand, and this again was larger than that of the chilled metal. This resembled a light grey pig iron in appearance, and was of the structure of a coarse-grained steel. It showed no signs of chilling at the sides, where it touched the ingot mould. In every case, however, the texture was slightly finer on the outsides of the bar than within them. Microscopic sections of these were compared with others taken from samples of coke pig iron, and copies of the photographs are shown. One of the coke pig irons taken for comparison was selected from its composition being similar to that of the charcoal pig iron :—

Total Carbon.	Mn.	Si.	S.	P.
3·89	0·6	2·42	0·04	1·0

In addition there was 0·04 of copper. In fracture, too, it closely resembled the charcoal iron. In only two important points, indeed, did it differ. In the first place, mechanical tests of the two metals gave very different results, and in the second, microscopic examination showed that the texture of the two metals differed considerably. It was found, too, that the results of the mechanical tests and of the microscopic examination were closely related to each other, and apparently directly so. In the charcoal pig iron, which gave the better results in the mechanical tests, the graphite particles were much more widely and evenly disseminated, and they crossed one another frequently, and the slide showed that in this sample of metal there was a much more homogeneous admixture of the component constituents than was the case in the coke pig iron.

In connection with these experiments the author describes another in which a thin coating of nickel, electrically deposited, is produced on the surface of the metal under examination. The different varieties of iron present in the pig iron under examination behave differently in the bath, probably owing to their different degrees of conductivity, and of course

this was also the case as regards the graphite present. The result is that a thin irregular coating of nickel is produced on the metal which permits of the various constituents being very clearly seen, and the author thinks that the results obtainable in this way are so satisfactory as to render it desirable that this method should be further investigated.

E. Heyn * discusses the possibility of forming a judgment as to the properties of pig iron by an examination of the fracture, and K. Glinz † replies to him. The former does not consider that it is possible to distinguish between charcoal and coke pig iron by means of microscopic examination. He considers that if the original chemical composition was the same, any subsequent differences in the appearance of the fracture of the metal must be due to differences in the way the metal was cooled. One possibility of difference exists in that coke pig iron may after solidification contain more dissolved gases than charcoal pig iron, but the presence of such dissolved gas cannot be detected microscopically. He also criticises Glinz's suggestion as to coating the section intended for microscopic examination with a thin film of another metal.

The Allotropic Modifications of Iron.—M. Galy-Actié ‡ describes some experiments which tend to confirm the existence of two allotropic varieties of iron. The metal used contained no carbon, and only a trace of phosphorus. It was drawn into wire eight millimetres (0·315 inch) in diameter, and cut up into a thousand small cylinders thirteen millimetres (0·51 inch) high, which were annealed at 1000° C., and the stress-strain curves under compression were obtained. The specimens proved very homogeneous. Crushing commenced at 11·113 tons per square inch, with a well-marked breaking-down point. The permanent set under this load was $\frac{1}{10}$ millimetre ($\frac{1}{25}$ inch). If, after the set had appeared, the load was relieved and immediately reapplied, crushing only recommenced when the highest pressure previously attained was reached, and the new stress-strain curve exhibited no breaking-down point. If, however, some hours were allowed to elapse before reapplying the load, the cylinder would support without fresh crushing a load considerably in excess of the highest previously applied; and when finally crushing did occur, the event was characterised by a well-marked yield-point. It was thus possible to raise the yield-point of the material far above its initial value. All cylinders annealed after heating to a temperature exceeding

* *Stahl und Eisen*, vol. xx. pp. 37-38.

† *Ibid.*, vol. xx. pp. 38-39.

‡ *Comptes Rendus de l'Académie des Sciences*, 1899, p. 1230.

850° C. showed a well-marked yield-point; but if quenched from this temperature and then tested at once, the yield-point disappeared, the stress-strain curve becoming uniform throughout. If, however, a certain time was permitted to elapse before testing the specimen, the yield-point would make its appearance, and this recovery of the metal to its primitive condition could be hastened by applying quite a moderate heat. If the metal was quenched from a temperature below 850° C., the yield-point was always present. These experiments seem to show that the β -iron can be produced at ordinary temperatures, either by mechanical deformation or by quenching, but is essentially unstable, and gradually changes into α -iron.

The Critical Points of Iron.—F. Osmond* deals with the question as to what is the inferior limit of the critical point A_2 . The various methods of determining this point, and the interpretation that is accorded to the deductions from them, are discussed. The various investigations that were examined and criticised give the following figures:—Roberts-Austen, between 600° and 550° C.; Curie, about 550° C.; Arnold, between 525° and 400° C.; Morris, about 420° C.; Howe, below 260° C. These discrepancies are ascribed to the variations in the purity of the iron; purer irons, such as electrolytic iron, give the highest figures.

H. M. Howe† subsequently discusses the critical ranges in iron and steel, especially as regards the magnetic properties and the changes from β to α iron, as bearing on the existence of this limiting temperature for A_{r_2} . The author also deals with the nomenclature of the subject.

The Magnetic Properties of Iron and Steel.—E. Schmidt‡ describes the magnetic investigation of iron and kindred metals. The subject is considered in all its aspects, the more modern magnetic methods, as connected with those of chemical analysis, receiving special consideration. The work is divided into three sections, the first of which deals theoretically with magnetism, the second with methods of investigation, and the third with the magnetic properties of iron and its kindred metals. This latter portion occupies about half the book. The three metals, iron, nickel, and cobalt, with their alloys, form the mag-

* *Metallographist*, vol. ii. pp. 169-186.

† *Ibid.*, pp. 257-261.

‡ *Die magnetische Untersuchung des Eisens und verwandter Metalle*. Halle, 1900, p. 145.

netic group of the elements. Iron materials are magnetically very wanting in homogeneity. Two samples from a large iron ingot may very likely show altogether different magnetic behaviour the one from the other. This is no doubt chiefly due to the fact that chemically the composition of the metal varies in different parts of the same ingot, and further, that the material has not been subjected to identically the same mechanical treatment in all its parts. Experiments have shown (1) that probably magnetically the most homogeneous material is that obtained by careful casting; (2) that a careful annealing and cooling down is advantageous; but (3) that it is not possible to render every material magnetically homogeneous by annealing. The author divides the different varieties of iron and steel into those which are magnetically "soft" and those which are magnetically "hard." The former readily becomes highly magnetic, and as readily loses its magnetic condition. This includes the soft varieties of weld and ingot metal. A material is magnetically hard which is hard to magnetise, but which does not readily lose this character when once it has attained it. It is on account of this property that different kinds of hardened steel are used for permanent magnets. Cast iron occupies magnetically a point between the hard and soft varieties. The author considers the causes of these variations. All mechanical treatment which causes a change in the molecular arrangement of the metal influences its magnetic properties. Carbon hardens wrought iron magnetically, and manganese, silicon, and phosphorus exert a similar influence. Carbon acts in different ways, according to whether it is "free" or "combined." Chromium and tungsten exert a similar influence. The chief points to be remembered are that in the case of soft iron all mechanical influences are to be avoided as far as possible which cause changes in the molecular structure of the metal. Further, that in many cases annealing may improve the quality of the metal. The best chemical composition to produce a given magnetic character cannot at present be definitely stated. The permeability of iron under otherwise equal conditions is, however, usually higher when the metal is purer. The difference existing between weld and cast metal is but slight, and many kinds of weld iron may even be less satisfactory than some of the better cast steels. The magnetic influence of nickel on steel castings is remarkable. An alloy with 5 per cent. of nickel may with a strength of field of 50 equal pure iron. A low percentage of nickel, on the other hand, has an entirely opposite effect, as the author shows in the case of a steel with just under 1 per cent. of nickel.

The author in dealing with cast iron considers the degree of influence exerted by its several constituents, and cites the results obtained in various experiments. To the results observed brief reference has already been made at the commencement of this abstract. The best magnet steel makes a poor magnet if it is not hardened at the correct temperature. For most steels this lies between 800° and 900° C. Small quantities of boron, silicon, and manganese appear in this connection to have no influence on the metal, while less than 4 per cent. of nickel, chromium, or copper improve the metal to be used for permanent magnets. The best kinds of steel to be used for this purpose are, however, tungsten and molybdenum steels. Even when as much as 1·7 to 2 per cent. of carbon is present in the metal, both tungsten and molybdenum exert a distinctly improving action. The author also refers to manganese steel and other alloys.

C. Maurain * considers generally all questions related to the magnetisation of iron. To the researches which dealt with the magnetisation of permanent magnets succeeded others dealing with magnetic induction, and these were followed by applications of their results in practice. In electric machines masses of iron are often submitted to the action of the magnetic field, which in nearly all cases varies periodically. The author passes to a consideration of magnetic hysteresis, and to other matters generally connected with the subject under consideration.

H. Kamps † discusses the influence of annealing on the magnetic properties of ingot iron sheets. The author points out that the exact connection existing between the chemical composition of iron and its magnetic properties is still unsettled. The experiments that have so far been made have shown little more than that the main groups into which the carbon contents divides the various varieties of iron differ also magnetically from each other. The author refers to the great losses of electric energy by conversion into heat in connection with dynamo machines and transformers, and to the use of the softest of ingot iron sheets. He shows that, in addition to the chemical composition of the metal, the mechanical and thermal treatment to which it has been subjected is a matter of the greatest importance, and now deals with the influence exerted on the magnetic properties of the metal by annealing.

He points out that an investigation, to be complete, should take into consideration the influence exerted by varying the height of the maximum temperature reached in the annealing, by altering the duration of

* *La Magnétisme du Fer*. Paris, 1899, 8vo, pp. 100, 20 figs., 2 francs.

† *Stahl und Eisen*, vol. xix. pp. 1120-1125.

the annealing process, and by variations in the rate of heating or cooling during annealing, or by any departure from the regular course of temperature change. Only in this way would it be possible to explain why annealing seems sometimes to improve and at others to deteriorate the magnetic quality of a sample of iron. The author has himself made a series of experiments to ascertain what influence is exerted by the relative duration of the annealing. The results attained were, however, but negative, as it was found that within the temperature limits comprised in the author's experiments the relative duration of the annealing appeared to be without influence. The maximum temperatures reached in these experiments did not differ very much from each other, but the duration of the annealing itself varies between 35 and 48 hours. He describes the way the experiments were performed, and gives the results obtained. Annealing in one set of experiments improved the metal magnetically, and in another made most samples distinctly worse, whilst others, which in the first set had given poor results, were improved in quality. All the samples were subsequently submitted to a third annealing, and one of long duration. Every sample was subsequently found to have deteriorated magnetically. It would seem, therefore, that for every sample of iron annealing can only produce a definite degree of improvement, and that further repeated annealing either does no good at all or else actually deteriorates the magnetic quality of the metal. The author makes various theoretical deductions to account for this, and deals with the questions: (1) How can annealing alter the magnetic properties of a sample of iron? (2) How is it that this alteration is in the one case an improvement and in the other a deterioration of the quality of the metal? and (3) Why does one and the same annealing process act differently on different samples?

Hardening carbon and carbide carbon in steel can be separated from each other chemically, the carbide carbon being only soluble in hot acids, while the hardening carbon escapes as strong-smelling hydrocarbons when the metal is dissolved in cold hydrochloric or sulphuric acid. The allotropy of iron, on the other hand, can only be brought to a high degree of probability by physical reasonings. This fact, and the fact that as the percentage of carbon increases the critical points draw closer and closer together, until in high carbon steel they merge into a single critical point, make it readily understandable that many equally probable theories may exist for the explanation of the hardening process. He considers that changes in the magnetic properties are due more to allotropy in iron than to changes in the form in which the

carbon occurs, giving his reasons for this, and he brings other facts forward in support of the allotropic theory. The alteration in the magnetic behaviour of annealed iron is due, he considers, to the changes in allotropic form to which the metal is then subjected, and to the relative ratios which the "hard" and "soft" varieties of iron bear to each other in the metal after it has been annealed. The author is further of opinion that, to avoid an absence of magnetic homogeneity, it would be best to continue the annealing to a definite maximum temperature, which must rise higher than the maximum critical point, and that the cooling down should be equally slow and regular at all the critical points, conditions which, he adds, are likely to be frequently difficult of application.

The chemical composition of the metal is undoubtedly always of influence on the position of the critical points, and the mechanical treatment to which the metal has been subjected is possibly also of importance. The author briefly passes in review the way the chemical composition affects the critical points, and then proceeds to deal with the influence exerted on the magnetic properties by the "size of the grain" of the metal, and he adds that the higher the temperature to which metal is heated on annealing, and the more slowly it is cooled, the larger is the grain. Other points are also dealt with.

S. W. Richardson * has experimented upon four alloys of iron, containing respectively 3·64, 5·44, 9·89, and 18·47 per cent. of aluminium. The temperatures used ranged from 83° C. to 900° C. The chief conclusions to be drawn from the experiments may be summed up as follows:—(1) The alloys behave magnetically as though they consisted of two distinct media superposed. (2) The general roundness of the curves, and their lack of abruptness near the critical point, seems to indicate that the alloys are heterogeneous in structure. (3) The permeability decreases with rise of temperature near the critical point, until a minimum value is reached, when further rise of temperature produces very slight diminution, if any, in the permeability. (4) The experiments suggest that the maximum value of the permeability for an alloy containing 10 per cent. aluminium is reached at about 90° C. (5) An alloy containing 18·47 per cent. of aluminium has a critical point at about 25° C., and gives no indication of temperature hysteresis. This alloy probably has a maximum permeability much below 90° C. The author has found that at high temperatures there is a second maximum

* Paper read before the Physical Society, October 27, 1899.

in the induction curve. This maximum becomes less and less noticeable as the field is increased.

A note by W. F. Barrett * on the electric and magnetic properties of aluminium and other steels deals with the electrical conductivity of various alloys, and discusses the effect of composition and annealing upon the value of the conductivity. The second part of the note refers to magnetic effects. The most remarkable effect produced by aluminium on iron is the reduction of the hysteresis loss. The permeability of nickel steels is shown to be very much influenced by annealing. It is found that the addition of a small quantity of tungsten to iron hardly affects the maximum induction, yet increases the retentivity and coercive force. The experiments show that the best steel for making permanent magnets is one containing $7\frac{1}{2}$ per cent. of tungsten.

F. Osmond † gives the results of some tests of steel suitable for permanent magnets, and gives the treatment requisite for special steel alloys.

The Law of Phases.—H. Le Chatelier ‡ discusses the application of Gibbs' "Law of Phases" to alloys. This deals with the possible number of homogeneous substances which can be present in a body for a given number of independent constituents. The author takes iron and carbon as examples and applies the law.

The Flow of Steel.—H. V. Loss § discusses the flow of steel under three conditions: (a) when the steel is absolutely free to flow in any direction, as in shearing; (b) when the material is partly free and partly confined, as in punching; (c) when the material is wholly confined in dies, as when upsetting rounds and squares or bridge eye-bars, also as when flanging and riveting. Diagrams are given of the power absorbed in shearing hot and cold billets, angle bars, and other sections, and in punching hot and cold metal with various forms of punches. Turning then to pressing in dies, the author considers the various cases where the dies and plungers are movable or fixed or both movable, and gives power diagrams and figures for all the cases.

* Paper read before the Physical Society, October 27, 1899.

† *Comptes Rendus de l'Académie des Sciences*, June 19, 1899.

‡ *Ibid.*, January 8, 1900; *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, vol. v. Series v. pp. 118-119.

§ *Journal of the Franklin Institute*, vol. cxlviii. pp. 461-473; vol. cxlix. pp. 26-40, 139-140.

The Coefficient of Expansion of Iron.—H. Le Chatelier* has investigated the expansion of iron and steel at high temperatures. Three periods are distinguishable. The first embraces the lower range up to the beginning of molecular changes, the last commences where these changes are complete, and the second takes place in the changes of condition themselves. During the first period (up to 1375° F.) the coefficient of expansion is fairly constant, averaging 0·000014; at 1400° F. it is 0·000017. The second period shows a great variation in results, depending upon the carbon contents to a great extent. The molecular changes are not strictly reversible, and consequently the following results are only given tentatively:—

Carbon, per cent . . .	0·05	0·20	0·50	0·80	1·21
Critical point . . .	1550° F.	1415°	1345°	1345°	1335°
Contraction, per cent. . .	0·26	0·23	0·21	0·08	0·10

There is much variation in the contractions, many of them being accompanied by expansions which modify the results considerably. Very likely this is due to two separate effects coming nearly together and overlapping. Thus the molecular change in the iron, which means a contraction of 0·26 per cent., may be accompanied by a solution of carbide which at 0·9 per cent. carbon gives an expansion of 0·26 per cent., or exactly neutralises the effect.

The Effect of Heat Treatment on Steel.—R. G. Morse† describes the result of tests on the effect of heat treatment upon the physical properties and microstructure of medium carbon steel having the following composition:—

C.	Si.	Mn.	P.	S.
0·343	0·027	0·221	0·0266	0·0037

Round test-pieces, $\frac{3}{4}$ inch in diameter and 1 foot long, were cut from rods from the same ingot, heated to temperatures ranging from 500° C. to 1300° C., and slowly cooled. Tensile tests were first made, and then the area of pearlite and ferrite was measured in polished sections. Microphotographs of the sections are given, and the results are tabulated and plotted as curves.

A. Campion‡ discusses the heat treatment and microstructure of steel, giving numerous quotations from A. Sauveur's papers, and then de-

* *Industries and Iron*, vol. xxvii. p. 426.

† *Transactions of the American Institute of Mining Engineers*, California meeting, 1899.

‡ *Journal of the West of Scotland Iron and Steel Institute*, vol. vii. pp. 72-90, 98-115.

scribing in detail a number of steels of which the analyses are as follows:—

Steel No.	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
1	0·06	trace	0·041	0·013	trace
2	0·09	0·028	0·068	0·019	0·16
3	0·19	0·070	0·044	0·053	0·45
4	0·35	0·100	0·038	0·030	0·50
5	0·67	0·302	0·022	0·041	0·57
6	1·21	0·093	0·013	0·029	0·65

Mechanical tests of each of these steels, treated in various ways, are then given, those for the 0·06 carbon steel being as follows:—

No.	Breaking Strain, Tons per sq. in.	Elongation per Cent. 3 in.	Cont. of Area per Cent.	Treatment.
1	23·3	36·3	56·9	As rolled.
2	22·4	33·0	53·8	Heated to 1000° C., cooled naturally.
3	21·1	36·6	51·9	Annealed.
4	32·2	9·1	20·8	Heated to 1000° C., quenched in water immediately.
6	32·2	12·0	19·2	Heated as in 4, but allowed to cool to 730° C. before quenching.

Similarly tests of the other steels are also given, and then the microscopic character of each sample is noted, special mention being made of the volume and appearance of the ferrite, pearlite, cementite, and martensite.

Another series of experiments was then made with the view of determining how and to what temperature steel should be heated in order to anneal it. Two steels were used having the following compositions:—

C.	Si.	S.	P.	Mn.
0·180	0·055	0·055	0·071	0·500
0·360	0·075	0·038	0·039	0·752

Both these steels were heated and cooled in many various ways, and the appearance and tensile tests are given in detail. The results show a fairly wide range with soft steel, but the best were attained by fairly rapid heating to a temperature not exceeding 750° C.; with hard steel the limits are closer. Much discussion ensued.

Influence of Low Temperature on Steel.—F. Osmond * discusses the influence of low temperature on certain steels, especially as regards the change in the magnetic state produced by cooling in liquid air on special samples of steels containing nickel, manganese, and carbon. When nickel, manganese, or carbon are added to iron, together or separately, in increasing proportion, the points of transformation of the iron are correspondingly lowered by nickel and manganese during either slow or rapid cooling, and by carbon during rapid cooling (quenching) only. When a certain proportion of the added elements is reached, the transformations can no longer take place. In short, the lowering of the transformation points of iron appears to be analogous to that of the freezing points of dissolving substances by the elements dissolved.

Colours of Heated Steel.—M. White † and F. W. Taylor give the following table of temperatures and the colour nomenclature that they prefer :—

Dark blood-red, black-red	990
Dark red, blood-red, low red	1050
Dark cherry-red	1175
Medium cherry-red	1250
Cherry, full red	1375
Light cherry, bright cherry, scaling heat, light red	1550
Salmon, orange, free scaling heat	1650
Light salmon, light orange	1725
Yellow	1825
Light yellow	1975
White	2200

A hitherto unpublished table of colours and temperatures by H. M. Howe is also given as follows :—

	Deg. Cent.	Deg. Fahr.
Dull red	625 to 650	1022 to 1157
Full cherry	700	1292
Light red	860	1562
Full yellow	950 to 1000	1742 to 1832
Light yellow	1050	1922
Very light yellow	1100	2012
White	1150	2102

* *Comptes Rendus de l'Académie des Sciences*, June 5, 1899; *Metallographist*, vol. ii. pp. 261-264.

† Paper read before the American Society of Mechanical Engineers, December 1900.

H. M. Howe * shows how little his own table differs from that given by the authors, and remarks upon the large differences they both show as compared with those given by Pouillet in 1836. The three tables are given side by side.

The Fracture of Steel Shafts.—R. Schanzer † has given the results of an investigation of a broken steel shaft, and includes numerous analyses taken across the section and many micro-photographs. A paper on the same subject by A. E. Seaton, containing the researches of J. O. Arnold, is summarised and the results compared. The structure of the shaft now investigated showed a marked separation of ferrite and pearlite, forming areas of different hardness and taking the form of strips parallel to the axis of the shaft. This gives rise to hair-cracks running in the same direction. Similar structure was found in a brittle steel plate and in other broken shafts. Nothing can be said as to the bearing of phosphorus on this structure, or as to its cause.

A. S. Younger ‡ deals with the corrosion and failure of propeller shafts, chiefly from the structural point of view, as regards the influence of the position of the bearings.

Nickel Steel.—D. H. Browne § gives a synopsis of experiment and opinion on nickel steel. His paper covers seventy-nine pages, and is divided into eight sections—Introductory, Physical Qualities of Nickel Steel, Molecular Relations of Nickel to Iron and Carbon in Nickel Steels, Uses of Nickel Steel, Cost, List of Makers in the United States, and Bibliography. The section dealing with the physical qualities is the longest, and it summarises the various points that fairly fall under that heading, such as the elasticity, elastic limit and ultimate strength, elongation and contraction of area, proportion of elastic limit to ultimate strength, influence of mechanical work and of heat treatment, annealing temperature, welding, effect of nickel on hardness, rigidity, effect of nickel on compressive strength, shearing strength, punching, segregation, coefficient of expansion, density, corrosion, electric and magnetic properties. Mention is made of the uses of nickel steel for boilers, shafting, engine forgings, railway axles and sleepers, ship plates, armour plate, structural beams and shapes, rivets, steam-hammer and rock-drill

* *Engineering and Mining Journal*, vol. lxi. p. 75.

† Paper read before the Institution of Naval Architects, April 1900.

‡ *Ibid.*

§ *Transactions of the American Institute of Mining Engineers*, California meeting, 1899.

piston-rods, bicycle tubing, tool steel, hydraulic cylinders, rifles and small arms, resistance wire, &c.

H. J. Williams * mentions a number of applications of nickel steel, and deals with the advantages of that material.

Copper in Steel.—A. L. Colby † has made an extensive series of investigations to show that small percentages of copper have no deleterious effect on the physical properties of steel. A steel shaft 15 inches in diameter by 14 feet long, corresponding in composition with the propeller shafts adopted by the United States Navy Board, but containing also 0·565 per cent. of copper, was forged without difficulty. Test specimens were doubled flat in the cold without showing cracks or flaws, and the tensile strength ranged from 64,680 lbs. to 68,010 lbs. per square inch, the contraction of area being 46·32 to 56·44 per cent., and the elongation in two inches 28·5 to 34 per cent. The material was well up to Navy requirements. In another series of tests the material, containing 0·553 per cent. of copper, was forged into a gun-tube, and satisfied the requirements of the United States Navy for a 6-inch gun, which demand a tensile strength of not less than 75,000 lbs. per square inch, combined with an elastic limit of not less than 36,000 lbs. per square inch, and an extension of 20 per cent. on two inches. Mild steel ship-plates containing 0·573 per cent. of copper, designed to have a tensile strength of 60,000 lbs., combined with an elongation of 25 per cent. in eight inches, passed the tests except a $\frac{1}{4}$ -inch plate which was rolled too cold, and had its elastic limit raised to 52,023 lbs. The bending and quenching tests of the bars cut longitudinally were also satisfactory, but some, bent transversely to the direction of rolling, developed cracks. The material could be successfully welded, only one of the specimens tested breaking at the weld, and even then the breaking load was 61,630 lbs. per square inch. Flanged cold, the material gave excellent results, and though most severely tested, developed neither defect nor flaw.

Other investigations were directed to merchant bars, rails, and to nickel steel, all containing copper. In the former commodities copper ranged as high as 0·397 to 0·486 per cent., and in the nickel steel up to 0·089 per cent. In no case was there a trace of red-shortness. By the usual methods of analysis the copper contained in steel is likely to be

* *Iron Age*, November 9, 1899, pp. 10–11.

† American Section of the International Association for Testing Materials; *Iron Age*, November 30, 1899, pp. 1–7.

under-estimated, but there is little tendency for copper to segregate. Good steel may contain as much as 1 per cent. of copper without suffering, provided only that the sulphur content is not also high, in which case the metal is likely to crack in rolling. If, however, the sulphur does not exceed 0.05 per cent., the metal can be rolled without trouble, even if as much as 0.75 per cent. of copper is present, whilst in any case the properties of the metal in the cold are unaffected. Full details of the results of the tests are given, and a bibliography of the subject is appended.

Testing Metals.—S. B. Russell* gives the results of some impact tests of small specimens of wrought iron and soft steel. The tests were made by a new method, under which the specimens were broken by tensile stress produced by a falling pendulum. The specimens are made of a special form, nicked at the centre so as to have an area at the nicked part of about 0.05 square inch. One end is fixed to the base of the machine and the other end to one end of a lever which is supported at its other end against a knife-edge. Both lever and specimen are placed horizontally. The lever is struck at the centre of percussion by a swinging pendulum weighing 103 lbs. in the experimental machine. The rise of the pendulum after it has broken the piece is measured, and due allowance is made for friction and inertia. This gives the number of foot-pounds of energy absorbed in breaking the test-piece. The resilience or shock resistance of steel cannot be predicted from its tensile strength and elongation, and the results are only comparative.

W. K. Hatt and E. Marburg† have made a preliminary report on the present state of knowledge concerning impact tests, and a summary of the observations of many observers are given in so far as they refer to the speed of testing in tensile tests and their comparison with tests under suddenly applied loads or impact tending to stretch the specimen.

P. M. Chamberlain‡ describes a machine designed to give a definite test of the machinable qualities of cast iron specimens, and at the same time to prepare the specimen for accurate tensile tests. It was built in the shops of the Lewis Institute, and serves as a part of the experimental laboratory equipment. It consists essentially of a lathe swung as a cradle dynamometer and an autographic apparatus. The lathe is

* *Engineering News*, vol. xlii. p. 323.

† American Section of the International Association for Testing Materials; *Engineering News*, vol. xliii. pp. 74-75.

‡ Paper read at the New York Meeting of the American Society of Mechanical Engineers.

adapted to prepare specimens 18 inches long. The carriage carries two cross slides, one with the testing tool and the other with forming tools. The autographic arrangement consists of a pencil attached to the carriage, and marks on a concave card concentric with the swing of the machine.

W. T. Magruder * describes three forms of supports for beams tested under transverse tests. The first consists of two rigid V pieces, the second of two flexible Z-shaped pieces, and the third of blocks resting on ball bearings in a pivoted cradle.

W. H. Kenerson † describes an extensometer which is capable of tracing stress-strain diagrams and at the same time giving micrometer readings.

W. J. Keep ‡ gives results of a series of tests to determine the action of cast iron bars under impact, the blows being delivered transversely to the length of the bar and the latter acting as a beam. The author stated that he has been unable to devise any mathematical formulæ by which the deflection of a test-bar of a given size with a given blow can be computed from the deflection of a test-bar of any other size, or from the deflection of a bar of the given size with any other blow. There seems no better way to determine the resilience of a material than to support a test-bar at the ends and deliver blows at the centre. After a test-bar has been tested in this way, it is desirable to find its resistance to impact without any distortion as a test of brittleness. To do this, a portion of the same bar should be clamped on the anvil of a testing machine so that one end shall project. Blows should be delivered on the projecting end. Barba has suggested taking a test-bar of steel 1.181 inch square, and filing a notch in the top and bottom, making the depth at that point only 0.835 inch. The object of the notches is to prevent any deflection before fracture. For general use it would not be safe to trust to the notches being made alike in shape and depth. For cast iron it would not do to cast the notch, as in cooling the formation of the grain around the notch would greatly weaken the test-bar.

For cast iron it would seem best to leave the bar with its original section, and deliver the blows as far from the clamp as $1\frac{1}{2}$ times the depth of the bar, which would be the proportionate distance suggested by Barba. An inch bar would receive blows $1\frac{1}{2}$ in. from the clamp and a $\frac{1}{2}$ -in. bar $\frac{3}{4}$ in. from the clamp. An examination of the diagrams

* Paper read at the forty-eighth meeting of the American Association for the Advancement of Science; *Engineering News*, vol. xliii. p. 18.

† *Engineering News*, vol. xliii. pp. 63, 97.

‡ Paper read before the American Society of Mechanical Engineers (New York Meeting).

obtained shows that some one size of test-bar must be selected for comparison. The size for cast iron which would seem to give the best results is a bar 1 in. by 1 in. by 24 in., struck with a 50-lb. hammer. This has the same relative proportions as a bar $\frac{1}{2}$ in. by $\frac{1}{2}$ in. by 1 in., and if a 25-lb. hammer is used, the record is the same as with a 1 in. by 1 in. by 24 in. bar with a 50-lb. hammer; but this does not take into account the grain due to size of casting.

The Fracture of Test-Pieces.—Rudeloff* discusses the appearance of the fracture of broken test-pieces, and gives illustrations and results of a large number of tests of test-pieces 0·4, 0·8, 1·2, 1·6, and 2 inches long, and also of test-pieces in which rounded and V-shaped grooves had been turned. The elastic limit is not affected until the length is less than 0·4 inch, but the ultimate strength rises when the length is below 1·2 inch, while the reduction of area decreases with the length. All specimens 0·4 inch or more in length showed cup-shaped, fibrous, velvety fractures, and the grooved specimens gave a flat lustrous and finely granular appearance. The behaviour of a test-piece is confined in the first place to that of a bundle of rods or wires, but the comparison only holds to a limited extent, as the friction between the neighbouring rods is not sufficient to be akin to the cohesive force which necessitates lateral flow. The outer layers stretch more than the inner ones, but the piece breaks first on the inside, and this may be due to the strains set up by the outer layers. The effect of slow and sudden stress is also dealt with.

Malleable Cast Iron.—E. C. Wheeler† discusses the physical characteristics of malleable cast iron. After referring to the methods of testing, the influences of heat conditions in the furnace are dealt with in so far as they affect the physical properties, and it is shown that steadily applied and continuous heating is of great importance, as uneven heating produces bad results both in casting and annealing. To produce soft castings, the packing should be charged with sal ammoniac. As regards the composition, manganese in the most recent practice is kept high, and the effect of that and other elements is considered. The author speaks highly of a coke iron low in silicon and carbon, with reasonable amounts of phosphorus and sulphur, cast in chill moulds. It is especially important that the composition of the product should be uniform, and therefore the practice of casting the whole charge into a heated

* *Baumaterialienkunde*, vol. iv. pp. 85–95.

† *Iron Age*, November 9, 1899, pp. 4–7.

ladle is beneficial. Much difference exists between the first and last runnings from a furnace. The shrinkage and tensile tests are then discussed with reference to the sizes of the test-bars to be adopted, and the author also deals with the several advantages of basic malleable iron. A number of analyses and tests are given to illustrate the various points brought forward.

Standard Specifications.—A joint meeting has been held of the Association of American Steel Manufacturers and Committee No. 1 of the American Section of the International Association for Testing Materials, and has considered the preparations of standard specifications for—(1) Bridge and ship materials; (2) building materials; (3) rails; (4) boiler materials; (5) axles, tires, &c.; (6) forgings; (7) castings; (8) wire.

C. A. Meissner * gives specifications for cast iron gas and water pipes, showing the methods to be adopted in casting, testing, and inspection generally.

Bridge Steel.—Specifications have been published † of the requirements for the steel wire and castings to be used in the New York suspension bridge. Steel for wire is to be made in acid-lined open-hearths entirely from pig iron containing less than 0·06 of phosphorus and 0·05 of sulphur. The contents of the finished steel must not exceed :—

P.	S.	Mn.	Si.	Cu.
0·04	0·03	0·50	0·10	0·02

The steel is to be cast into bottom cast ingots in groups of not less than six, each not larger than 16 square inches in cross section, and weighing not more than 5000 lbs. Castings are also to be made from acid-lined open-hearth steel, but scrap may be used in the bath, and the finished steel must not exceed—

P.	S.	Mn.	Si.
0·06	0·04	0·80	0·35

Tests of Steel Balls.—J. F. W. Harris ‡ has tested a number of steel balls by crushing between other balls and between flat steel plates. Since the first tests on balls, a steel sufficiently hard and suitable for

* *Journal of the Mining Society of Nova Scotia*, vol. v. pp. 47-53.

† *Engineer*, vol. lxxxviii. p. 627.

‡ Paper read before the American Society of Mechanical Engineers.

the flat crushing surfaces has been found. The following results showing the breaking pressure in pounds are given :—

	Diameters.					
	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	1
Between two balls . . .	2,000	4,000	8,000	15,000	22,000	60,000
Between flat plates . . .	2,000	5,000	12,000	20,000	32,000	90,000

Steel Rolls.—In a letter addressed to *Stahl und Eisen* * attention is drawn to the use of cast steel rolls. These are usually of open-hearth steel, with from 0·6 to 0·7 per cent. of carbon, 0·5 to 0·7 of manganese, and 0·2 to 0·4 of silicon. The material has a tensile strength of from 51 to 57 tons per square inch. For finishing rolls steel is not generally applicable. The local wear is considerable, and the metal under treatment on leaving the rolls is apt to stick to them. They have some advantages, however, to which the writer draws attention.

Steel for Tube Manufacture.—Steel required for the satisfactory manufacture of tubes, especially bicycle tubing, according to A. E. Tucker, † must be of exceptional character to allow a 6-inch bloom to be drawn down to tubes 10 to 18 feet long, 1 inch in diameter, and $\frac{1}{30}$ -inch in thickness. Amongst the factors that militate against success is the imperfect mixture of the manganese additions in the ladle. Unless there is a very thorough incorporation, hard spots and heterogeneous ductility are likely to result. Segregation is similarly objectionable, while honeycombing and surface or other cracks are liable to development in the subsequent operations. The chemical composition of steel which has been successfully used shows a considerable range, but, as a rule, harder steels are employed than was formerly the case. Seven analyses of good tubes are given, showing the following range :—

Si.	P.	S.	Mn.	C.
0·009-0·569	0·010-0·056	trace-0·030	0·248-0·520	0·087-0·703

Some tests made by Oberlin Smith ‡ are given to show the varying strength due to different treatment. The methods of drawing, annealing, and pickling the tubes are briefly referred to. *

An account is given § of an interesting case which occurred in connection with the Siboga Expedition, which is engaged in scientific deep-sea

* Vol. xix. p. 1079.

† *Proceedings of the Cycle Engineers' Institute*, vol. i. pp. 143-163.

‡ *Iron Age*, August 3, 1899, pp. 10-11.

§ *Der Ingenieur*, February 10, 1900; *Stahl und Eisen*, vol. xx. p. 232.

dredging exploration in the Indian Archipelago. The net was let down to a depth of 4391 metres (nearly $2\frac{3}{4}$ miles). This net had attached to it a piece of drawn iron tubing, 6 feet 6 inches long, $2\frac{1}{4}$ inches wide, the metal of the pipe being 0.24 inch thick. To the ends of this tubing the net was attached, and to give it greater strength the two ends had been welded together. Quite unintentionally this resulted in making the pipe air-tight, and in this form it was quite unable to resist the action of 440 atmospheres pressure which the great depth of water in which it was lowered had exerted upon it. It was not only blown in, but this had been done with such force that the pipe had not only been pressed flat, but had been burst along its whole length, and pieces of the pipe were subsequently found in the net. It is observed that the whole had been suspended from a steel wire, the winding up of which from so great a depth took several hours to complete.

Rails.—In a paper * on the development of the manufacture and use of rails in Great Britain, Sir Lowthian Bell traces the history of the manufacture of iron and steel from the earliest times, with particular reference to the conversion of the metal into rails. An account is also given of various experiments on the deflections of rails under trains travelling at different speeds, with a comparison of the relative values of rails arrived at by testing them to destruction under a falling weight.

Thomas Andrews † gives an account of an experimental investigation of the deterioration undergone by rails laid in tunnels, describing particularly a set of experiments made on a rail which had done its duty in such a situation. The results of the experiments are given with reference to the mechanical, physical, and chemical changes produced in the rail whilst it was in use.

Of the forty-four leading railways in America, with 104,700 miles of road, no less than thirty-three, with 85,566 miles, have adopted the standard sections proposed by the American Society of Civil Engineers, and many other lines use very similar sections. Some question has recently been made as to whether the corner with its $\frac{5}{16}$ -inch radius has caused an increased wear of the wheel tyres, but on inquiry of the leading lines this does not appear to have been noticeable. ‡

A report § upon the best form, length, and method of constructing railway rails has recently been made by a committee appointed by the

* Read before the Institution of Civil Engineers, April 10, 1900.

† Paper read before the Institution of Civil Engineers, April 10, 1900.

‡ *Engineering News*, vol. xliii. pp. 208-211.

§ *Mechanical Engineer*, vol. v. pp. 526-527.

American Railway Engineering and Maintenance of Way Association. *Inter alia*, the section of rails in use, their chemical composition, and the past and present methods of rolling are dealt with.

Tests of Armour Plates.—In some notes on recent advances in war material, it is observed that steel armour equivalent to $1\frac{1}{4}$ times its thickness of wrought iron has developed into the Krupp process plate with a figure of merit between $2\frac{1}{2}$ and 3. The effects of chromium and nickel are mentioned.*

Illustrations have appeared † of the back and front of a Krupp process plate made by J. Brown & Co. for the Norwegian navy. The plate measures 8 by 6 feet, and is 5·9 inches in thickness. It was tested with six 6-inch steel armour piercing projectiles, weighing $102\frac{1}{2}$ lbs. each, at velocities ranging from 1902 to 2182 foot-seconds. The penetration ranged from $3\frac{5}{8}$ to 5 inches, and the bulging at the back from $1\frac{1}{4}$ to $2\frac{3}{8}$ inches. All the projectiles were smashed.

A test was made at Indian Head on September 19, 1899, of a Krupp process plate made by Carnegie for the Russian vessel *Retvizan*. The plate was 5 inches in thickness, and about 92 by 127 inches in area. Five shots were fired, all 5-inch shells, with striking velocities of 2057 to 2082 foot-seconds. In all cases the shells broke up, flaking the surface of the plate, but not cracking it. An illustration of the tested plate is given.‡

An illustration is given of a Carnegie-Krupp process plate for the Russian battleship *Retvizan* tested on December 28, 1899. The plate measured $11\frac{1}{8}$ by $7\frac{3}{4}$ feet, and was 8 inches in thickness. Four 8-inch projectiles were fired with striking velocities of 1837, 1791, 1815, and 1834 foot-seconds, and striking energies varying from 5626 to 5994 foot-tons. The plate defeated the attack with insignificant penetration, but appeared to be somewhat softer than was expected.§

Another of these plates, 6 inches in thickness and 8 feet 7 inches by 7 feet $6\frac{1}{2}$ inches, was also || tested by five blows from a 6-inch gun. In the hardest test the striking velocity was 1919 foot-seconds and the striking energy was 2553 foot-tons. All the projectiles broke up with little effect.

The present condition of the armour plate question in the United States is discussed, ¶ and there is a history of the matter compiled by

* *Engineer*, vol. lxxxix. p. 21.

† *Ibid.*, p. 124.

‡ *Ibid.*, vol. lxxxviii. p. 468.

§ *Ibid.*, vol. lxxxix. p. 233.

|| *Ibid.*, p. 423.

¶ *Ibid.*, pp. 269-270.

the American Iron and Steel Association extending over thirteen years. During the past five years there has been a practical deadlock between the Government and the manufacturers over the quality and price for certain warships. The recent rise in prices has further complicated matters.

Illustrations are given * of a number of tests of protective deck-plates made by the Carnegie Company for Russia, the Krupp process of hardening being employed. The plates were tested under glancing fire at an angle of 15° , and striking velocities ranging from about 1000 to 1600 foot-seconds, 6-inch shells being used. The plates were 1 to $1\frac{1}{2}$ inch in thickness, and the effect of the shots was to cause more or less deep bulges, sometimes accompanied by cracks, and of these results particulars are given.

The conditions for manufacturing and testing armour plates in different countries are discussed on general lines.†

Lord Hopetoun, in his Presidential address ‡ at the Institution of Naval Architects, dealt *inter alia* with the supply of armour plate, and some comments on this subject have also appeared.§

An illustration has appeared || of a Schneider hard-faced armour plate tested in May 1898. The plate is 9·843 inches in thickness, and endured three shots; the first weighing $317\frac{1}{2}$ lbs., striking with a velocity of 2110 foot-seconds; the second and third each weighing $165\frac{1}{2}$ lbs., with striking velocities of 2576 and 2664 foot-seconds. The plate has scaled, and shows thin cracks, but has entirely defeated the attack.

Illustrations are given ¶ of the front and back of a nickel Harveyed plate made for the Japanese Government by Vickers. The plate is 8 by 8 feet and $8\frac{3}{4}$ inches in thickness. It endured three blows from a 9·2-inch steel Holtzer projectile weighing 380 lbs., and having striking velocities of 1700, 1700, and 1800 foot-seconds. No cracks are shown.

A treatise by L. Baclé** on armour-plate has recently appeared. It is divided into twelve chapters, and gives a general historical review of the application of armour to naval purposes, the use of different kinds of metal in their manufacture, a discussion of the

* *Engineer*, vol. lxxxviii. pp. 395-396.

† *Engineering*, vol. lxix. pp. 435-438.

‡ April 1900.

§ *Engineering*, vol. lxix. pp. 483-484.

|| *Engineer*, vol. lxxxviii. p. 544.

¶ *Ibid.*, p. 575.

** *Les Plaques de Blindage*. Paris, 1900. A copy of this work is in the Library of the Institute.

penetration formulæ in use, conditions of acceptance for different types of ship-plates, an account of the leading trials before 1891, and of those between 1891 and 1895, especially with hardened steel, and of the trials since 1895 with various types of projectiles. One chapter is devoted to armour for land defence, and the last section deals generally with the progress of manufacture. Tabulated statements of a large number of trials are appended, and numerous illustrations are given in the text.

CHEMICAL PROPERTIES.

The Solution Theory of Iron and Steel.—Baron H. von Jüptner * further considers the solution theory of iron and steel. He deals in the first instance with the subject mathematically, and shows that the change in the molecular size of carbon dissolved in iron reaches a maximum between the temperatures of 1200° and 1225° C. In the case of those alloys whose constituents yield isomorphous mixtures, the molecular weights of the two constituents are approximately inversely proportional to the molecular melting-point diminutions pertaining to them. The author next considers in detail the curve yielded by the melting-points of pure carbon-iron alloys, as given by Roberts-Austen. He thinks that the eutectic alloys may only then have a constant solidifying point when they form the major portion of the alloy. In any case, when the eutectic alloys separate out, the molecular size of the dissolved substance must undergo at least slight variations. The author thinks that possibly Arnold's sub-carbide may not be a simple solution of carbide in iron, but perhaps a compound such as $\text{Fe}_3\text{C}.\text{Fe}_{21}$. Dealing in the next place with the austenite curve, starting from the theory that it is at least not impossible that austenite may consist of a solution of carbon in its elementary form in iron, the author shows that in austenite both the free carbon and the free iron would appear to exist in the form of ions, that is to say, in an electric condition, and he thinks that this might account for the varying magnetic and thermo-electric behaviour of iron alloys at different temperatures; and further, that the free-iron ions might bring about that condition which Osmond denominates as γ -iron, and that such a dissociation of the iron molecule might take place at high temperatures even in pure iron. It is not possible, the author shows, to calculate the absolute values of their molecular weights in the case of the solid iron-carbon solution, and this, as he also adds, is scarcely

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 15-18, 29-31, 46-48, 56-59, 72-74, 86-88.

explainable without assuming at least two different conditions in which the iron may exist. The difference between the two kinds probably lies in their differing in the number of atoms occurring in their molecules. In all probability this molecular size increases as the temperature diminishes; that is to say, α -iron would correspond to much larger molecules than the allotropic forms which are stable at high temperatures. In the passage of α -iron into another form of iron a decomposition of the α -iron molecules must thus take place, and to produce this there must be an absorption of energy. Pionchon, as a matter of fact, has found that on heating iron between 660°C. and 720°C. , 5.3 calories become latent, evidently utilised in producing such a change in the iron. The author next deals with iron alloys showing only one critical point. These are those of iron with silicon, phosphorus, and tungsten. Each of these is separately dealt with. In all these cases the presence of a kind of iron differing from ordinary iron becomes apparent, but more particularly in the case of the phosphorus and tungsten alloys. Thus when Fe_3P and Fe_3W are separated out, and probably also when Fe_2Si separates, α -iron is simultaneously produced. Other deductions are drawn as to the composition of the compounds above referred to. The author next considers the method for the colorimetric determination of carbon, and points out, as regards the action of dilute nitric acid on steel, that if a colourless solution results with simultaneously a strong evolution of gas, ferrite may have passed into solution, while the intense black residue that may have been deposited might be the carbon dissolved in the martensite. The flocculent brown precipitate that forms is probably a nitro-product of cementite. The author, after considering the suggestions of other writers, refers to his own paper read before the Iron and Steel Institute at their Spring Meeting in 1897. With regard to the colouring power of the various forms of carbon, this may be placed in the following order:—

Carbide carbon	100.0
Total carbon	92.7
Pearlite carbon	80.0
Martensite carbon	52.0

They are therefore approximately in the following ratios:—

Martensite carbon	2
Pearlite carbon	3
Carbide carbon	4

Campbell has shown that iron carbide exists in iron in many polymeric forms, the more important of which are C_2Fe_6 , C_3Fe_9 , C_4Fe_{12} , and

C_5Fe_{15} . In annealed steel with less than 1.3 per cent. of carbon C_4Fe_{12} is the predominant carbide. As the percentage of carbon in the annealed steel increases, so does the percentage of carbon in the form of C_2Fe_6 . In hardened steel the latter occurs in larger quantities than it does in the same steel in its annealed condition. Bearing in mind that Saniter has stated that iron carbide begins to dissociate at as low a temperature as $800^{\circ} C$., the author points out that at the point at which martensite changes into pearlite a marked polymerisation of the carbide must take place, while above A_{r_2} , and apparently also about $100^{\circ} C$. below A_r , the molecular weights remain approximately constant in character. Above A_{r_3} the molecular weight diminishes again considerably, and this may be connected, at least in part, with the commencing dissociation of the carbide. The author considers that from the chemical point of view chiefly three kinds of carbon have to be dealt with:—Hardening carbon above the critical point, with the colouring capacity 2 (martensite carbon); hardening carbon below the critical point with the colouring power 3 (pearlite carbon); and carbide carbon with the colouring capacity. From various considerations the author arrives at the conclusions:—(1) That annealed steel contains no martensite hardening carbon, but that it does contain (in pearlite) carbide carbon and pearlite hardening carbon; (2) That hardened steel, in addition to the carbon forms contained in any cementite that may be present, contains martensite hardening carbon, and possibly also carbide carbon and pearlite hardening carbon; (3) That the iron carbide contained in pearlite is decomposed by cold dilute nitric acid into a portion which goes into solution (pearlite hardening carbon), and into a residue which only becomes soluble at about $80^{\circ} C$. (carbide carbon): the ratio existing between these appears to vary with the percentages of carbon; (4) That it is as yet impossible to say whether the carbide contained in martensite yields with cold dilute nitric acid only martensite hardening carbon, or whether the two other kinds of carbon above mentioned also form. If the colouring power is considered in connection with the molecular constitution of the carbide, martensite hardening carbon would represent 2 ($C Fe_3$), pearlite hardening carbon 3 ($C Fe_3$), and carbide carbon 4 ($C Fe_3$). The author suggests for these the names of bi-, tri-, and tetra-carbon. Thus in martensite chiefly "bi" carbon is present; in free cementite, "bi," "tri," and "tetra" carbon; and in pearlite, "tri" and "tetra" carbon.

The author observes that the various considerations he has dealt with show that carbon is soluble as such in pure iron, the following

table of solubility being given by the author, who also refers to the Roberts-Austen curve :—

Temperature, C.	The Saturated Iron-Carbon Solution contains in parts of Carbon—	
	Per 100 parts Solution.	Per 100 parts Iron.
3500	40.0	66.67
1260	5.5	5.82
1200	5.0	5.26
1142	4.5	4.71
1130	4.3	4.49
1030	1.5	1.54

It further appears that, at least in the alloys that are poor in carbon, the molecules of the dissolved carbon consist, between 1600° and 1300°, of two atoms, and that as the temperature diminishes, so the molecules increase in size, until at about 1150° C. about equal numbers of two- and three-atomed molecules are present in solution. As the temperature falls still further, iron carbide forms in the solution, probably in addition to some free carbon, this latter being the larger in quantity the greater the percentage of carbon in the iron. At first this free carbon, as austenite, remains in solution, but if the quantity increases beyond a certain limit the alloy separates into two parts. In one of these, austenite, free carbon exists in largest quantity, while in the other, martensite, iron carbide is the most important constituent. As the temperature becomes still lower the quantity of carbide increases, as also does that of the martensite, while the quantity of the austenite diminishes, until finally only martensite is present. In alloys poor in carbon, pure iron, ferrite, separates from the martensite at still lower temperatures, while in alloys richer in carbon a separation of cementite occurs. At still lower temperatures the conversion of martensite into pearlite takes place with simultaneously a rapid polymerisation of the carbide, which then consists chiefly of C_4Fe_{12} instead of the C_2Fe_6 which probably existed in more or less large quantities when the cementite separated.

Other elements present in iron behave in a similar manner. Silicon, for instance, also appears to be dissolved in its elementary form at high temperatures, and its molecules appear to contain about the same number of atoms as those of carbon. At lower temperatures, however, the silicon enters into combination with the iron and a solution of
1900.—i.

this compound, Fe_2Si , is present, and this subsequently separates out. The separation of other compounds, such as Fe_3P , takes place in an analogous manner, while others, such as ferrotungsten, appear to be mostly dissociated even at ordinary temperatures.

Such elements as manganese and nickel, whose alloys with iron represent isomorphous mixtures, behave in a somewhat different manner, whilst if no other element is present, these never separate out, yet as regards other elements also present they behave as a single simple solvent, and its influence on the solution phenomena of foreign elements depends on the way these dissolve in the several components. Thus while manganese appears to exert no marked influence on the size of the molecules of the dissolved elementary carbon and silicon, yet manganese is a far better solvent for these elements than is iron, and varieties of steel rich in manganese show no separation of martensite and austenite. This is probably due, however, to manganese hindering the formation of iron carbide. Silicon and phosphorus separate out as various polymers of iron silicide or phosphide. The author thinks that at least the phosphorus may exist in the form of a depolymerised phosphide, which corresponds with a "hardening phosphorus," and which, like the respective carbide, would be readily decomposed by acids.

The author next considers the behaviour of iron towards silicates, oxides, and sulphides. The former, slags, seem to be almost insoluble in iron. Such oxides as FeO and MnO , and sulphides such as FeS and MnS , are soluble to a considerable extent in iron, and are only separated out in the critical zone. In metals free from slag the separation of these substances only takes place when the metal is cold, but it is different when slag is present, the latter being a far better solvent for them than is the iron and tending to separate them from the iron. Silica behaves in a similar way to the oxides and sulphides. Thus the addition of ferrosilicon to oxidised metal gives a poor material, owing to the silica produced being separated out in dust form in the steel. If ferromanganese is added, however, in addition to the ferrosilicon, then manganese silicate results, and this easily separates from the molten metal, leaving a good material.

The author then proceeds to consider the changes that take place within the solid metal. These he deals with briefly, showing that such changes take place. In conclusion, the author refers to the present condition of microscopic investigation as regards iron and

steel, and he points out in what manner this is capable of being further widened in scope.

The Corrosion of Iron.—H. Baucke * refers to a case in which a number of new locomotive boiler-tubes showed themselves very badly corroded after being but a very short time in use. No deposit had formed inside the tube, but they were in a very bad state, extremely thin in places, and sometimes perforated. The metal used in their manufacture was a soft ingot iron, which had withstood in a satisfactory manner all the customary tests. The matter was all the more difficult to understand as other tubes had given satisfaction for two years and more. The possibility was excluded of the tubes having been burnt through, either by letting the water get too low or by the formation of boiler incrustation, by the fact that the water was kept at a proper level and that no incrustation had formed. There was no cause either for the belief that the water used was of such a character as to readily attack ingot iron at elevated temperatures. An analysis was made, not only of the metal composing the tubes that had failed, but also of the metal of other tubes that had proved perfectly satisfactory in practice. The results were as follows:—

	Good Tubes.	Bad Tubes.
	Per Cent.	Per Cent.
Carbon	0·106	0·033
Sulphur	0·024	0·057
Phosphorus	0·093	0·017
Silicon	0·061	0·009
Manganese	0·190	0·351

These analyses show considerable differences, yet not such as to at once show any great error in composition. The material of which the unsatisfactory tubes were made is at once seen to be typical, as far as its composition is concerned, of German basic Bessemer metal, containing as it does a low percentage of carbon and normal percentages of sulphur, phosphorus, manganese, and silicon. The origin of the material of which the good tubes were made is not easy to deduce from the analytical results. It has a high percentage of phosphorus and is presumably Scotch iron. The low carbon contents of the bad material is not abnormal, much ingot metal having been made of late

* *Stahl und Eisen*, vol. xx. pp. 260-263; 4 illustrations.

and worked up which contained only 0.03 per cent. of carbon. The author then examines the two materials microscopically and describes the method he employed. Even on polishing, the difference between the two metals became most marked. The good material was easily dealt with, but this was far from being the case with the other. It was extremely difficult to produce an even surface. Portions were constantly breaking away and holes forming. The bad material was therefore evidently too brittle. If from the two metals the outside portions were removed with a file, then the two metals showed no very great differences. Both showed the normal structure that is observable in low-carbon ingot irons, and both were somewhat coarsely crystalline. Microscopic examination of the tubes showed that on the inside both were alike, but that on the outside of the tubes there were considerable differences in the two cases. The depressions and holes which had been observed in the tubes that had given dissatisfaction were found to be all arranged in one straight line, and were of only local occurrence. The author thinks that gas inclusions may have been the cause of the faulty structure of the metal. In a note on this paper in *Stahl und Eisen* * it is pointed out that the corroded spots may have been due to drops of oil which fell on the tubes when the boiler was under repair. The acid of lubricating oil is well known frequently to give rise to boiler corrosion. That this was the case in this particular instance is to some extent rendered probable by the evidence afforded from the practice in the locomotive shops at Cologne and Frankfurt. In the former place weldless ingot iron locomotive boiler-tubes have long been used without corrosion of this kind having been observed, while at the latter, even after very short use, the tubes were found to be strongly corroded in exactly the same way as is described by the author in his paper. The cause of this difference was found to be that at Cologne the locomotive boiler was thoroughly washed out with soda after repairs, while at the shops at Frankfurt-on-the-Main this had not been done. Since then the washing out with soda has been performed at the latter place also, and now no more trouble is experienced there from corrosion.

Some experiments upon the durability of different metal coatings immersed in water are described by A. H. Sabin.† The plates used were of aluminium and of steel, and two coatings, a baked enamel and

* Vol. xx. p. 263.

† *Proceedings of the American Society of Civil Engineers*, vol. xxvi. pp. 206-210.

a shellac varnish, were found to be specially resistant. Some discussion on protective coatings in general ensued.

H. Smith * describes some tests on paints made in three different ways :—(1) By painting shallow iron dishes and exposing them to the action of slowly evaporating water ; (2) by exposing a set of painted iron plates to the action of the weather for a period of twelve months ; and (3) by exposing painted iron plates to the continuous action of water. Red-lead and similar paints gave the best results, followed in order of merit by zinc and white-lead paints.

Ferro-Chrome.—Hérault † treats a chrome ore with fluxes in an electric furnace until reduction has been effected, and then continues the action of the current on the fluxed mass until the whole of the iron, or a portion of it, as may be desired, is volatilised. The boiling-point of chromium being higher than that of iron, it is possible to enrich a chromium iron alloy in this way. The part played by the fluxes is not merely the ordinary one of producing a fusible slag, but, not being a very good conductor, it becomes more possible to regulate the current and to attain a higher temperature than would otherwise be possible. The necessary quantity of coke is added to the charge for reduction purposes. In his furnace the author uses from 20 to 25 per cent. of fluxing materials.

The Relations of Aluminium to Iron.—G. Melland ‡ deals with the relations of aluminium and iron, beginning with the alloys, and then going on to the use of aluminium in the treatment of malleable and cast iron. As regards the alloys, a summary of R. Hadfield's experiments, published in 1890, are given, after which the opinions of various authorities on the addition of aluminium in the manufacture of Mitis castings, and for similar purposes, are briefly discussed. The opinion once so widely held, that aluminium reduced the melting-point, has been shown to be fallacious, and the advantage of its use is now known to be due to its great reducing power on the oxides of iron and carbon monoxide in the bath. Further, in the manufacture of mild steel it is exceptionally useful, because it does not necessitate the introduction of carbon. The action of small amounts of aluminium upon steel is very similar to that of silicon, and in the

* *Journal of the Society of Chemical Industry*, vol. xviii. pp. 1093-1097.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. p. 78.

‡ Paper read before the South Staffordshire Iron and Steel Institute, March 24, 1900.

action of the metal upon cast iron this parallelism is just as remarkable. The observations of W. J. Keep are quoted, and it is stated that, with regard to the practical use of aluminium in the foundry—apart from its ordinary use as a softener of hard irons—it should be of the greatest value in connection with the casting of small objects in iron moulds, as the thinnest castings are quite grey and comparatively soft.

Palladium Steel.—Recently, at the University College, Sheffield, there was melted and cast probably the most expensive steel ingot that has been made in Sheffield. A steel was required to contain 22 per cent. nickel, 3 per cent. palladium, with carbon practically nil. Twelve and a half pounds of 25 per cent. nickel steel scrap were charged into the crucible and clear melted; then 6·32 oz. of palladium sheet (value £60, 14s.) were added to the charge. Though dead mild steels occasionally find their way through the bottom of the crucible before they are ready to pour, the whole operation was successfully completed, and the ingot rolled and drawn into wire.*

The Metallic Carbonyls.—H. A. Loos† and V. Lenher have made a study of the metallic carbonyls and their decompositions. The metals with which carbonic oxide combines are nickel and iron, and possibly palladium. Apparently analogous compounds with potassium do not appear to be carbonyls. These compounds were discovered by Mond, and have been applied to the production of nickel and to other uses. Their properties and reactions with various reagents are described in detail by the authors.

Analysis of Ancient Iron.—The following analysis has been published ‡ of iron taken from the jointing of the stones in the Parthenon temple, which was erected 438 B.C. :—

C.	Si.	S.	P.	Mn.	Fe (by diff.)
0·085	0·004	0·005	0·018	trace	99·888

* *Industries and Iron*, vol. xxvii. p. 409.

† *School of Mines Quarterly*, vol. xxi. pp. 182-191.

‡ *Engineer*, vol. lxxxix. p. 115.

CHEMICAL ANALYSIS.

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I.—ANALYSIS OF IRON AND STEEL.

Sampling.—Sampling pig iron is described by P. W. Shimer.* A tubular shield surrounding the drill-bit is provided with a small box into which it guides the drillings, so that they are collected without further attention. The device is attached to the stock or holder of the drill by a spiral spring.

An Electrolytic Laboratory.—O. Brunck † observes that in the last twenty years electrolysis has become such an important branch of analytical chemistry, that it can now be no more done without than volumetric and gas analysis. He now illustrates a suitable arrangement of a laboratory intended for electrolytic methods.

At the laboratory at the Mining Academy of Freiberg, in Saxony, the author states that the metallic deposits are usually not thrown down in platinum dishes, but that the beaker method is used instead, which possesses, among other advantages, that which consists in its being possible the whole time to watch the colour of the solution, and to better observe the evolution of gas. As cathodes, perforated platinum cylinders are used, which, on account of their much lighter weight, admit of much greater accuracy in the weighings than when platinum

* *Transactions of the American Institute of Mining Engineers*, February 1900.

† *Chemiker Zeitung*, vol. xxiv. pp. 56-58; 1 illustration.

dishes are employed. In this method, too, it is much easier to wash properly without breaking the current. The author refers to the advantages to be obtained by the use of the Winkler wire-net electrodes.

Determination of Carbon.—A. P. Ford and I. M. Bregowsky * give the following method for the determination of graphitic carbon in cast and pig iron :—

One gramme of the sample is dissolved in nitric acid (sp. gr. 1.12), preferably without boiling. When solution is complete, or nearly so, a few drops of hydrofluoric acid are added, more or less according to the amount of silicon present, and boiled a short time to drive off the hydrofluoric acid and to ensure complete solution of the iron. The acid solution is then diluted with four or five times its volume of water, and filtered by slight suction on a Gooch filter through asbestos, which should be digested in hydrochloric acid, and ignited until there is no further loss of weight, before the graphite is thrown on it.

After washing with hot dilute hydrochloric acid and hot water, the crucible with contents is dried an hour or an hour and a half at 120°, the length of time it is dried depending somewhat on the amount of graphite. The crucible is then cooled, weighed, the graphite burned off, and the crucible cooled and weighed again, the difference between the two weights being the graphite.

G. Auchy † points out that asbestos is preferable to filter-paper for collecting the graphite left on dissolving iron, but attention is called to the retention of water by asbestos. The process is not altogether free from sources of error, but these do not appreciably affect the result when the percentage of graphite is small. The graphite is not always pure carbon, but may contain small quantities of hydrogen, oxygen, nitrogen, and sulphur.

According to A. Carnot and E. Goutal, ‡ Blair separates carbon from iron by treating the sample with a solution of potassium cuprous chloride containing 15 cubic centimetres of hydrochloric acid in 200 cubic centimetres. The authors having tested the method, state that the temperature should not exceed 70°, otherwise there will be a loss of carbon. They, however, prefer their own process of treating the sample at 95° with the slightly acidified copper solution

* *Journal of the American Chemical Society*, vol. xxi. pp. 1113-1115.

† *Ibid.*, vol. xxii. pp. 47-48.

‡ *Journal of the Chemical Society*, vol. lxxvi. p. 809.

for about half-an-hour in a current of carbonic anhydride. Ferromanganese with more than 75 per cent. of manganese should be treated in the cold. The drying of the carbonaceous residue is often a source of decided loss.

Otto Herting* gives a reply to Murmann on the subject of the estimation of carbon, copper, and manganese in pig iron, wrought iron, and steel.

Heid's process is recommended for the estimation of the carbon. The iron is dissolved in copper-ammonium chloride, the impure carbon is collected on an asbestos filter, and well washed with hot water, and then with alcohol and ether. The filter is transferred to a Rose's crucible, dried at 120°, and weighed; the carbon is then burnt in a current of oxygen, and is represented by the loss in weight. To estimate graphite the sample is dissolved in dilute nitric acid, and the insoluble matter treated as above.

Determination of Phosphorus.—An illustration is published † of a small centrifugal machine for rotating the tubes used in the Goetz method of determining phosphorus by measuring the bulk of the molybdate. The appliance is driven by an electro-motor.

Determination of Manganese.—R. Namias ‡ uses Volhard's process when estimating manganese in samples of iron or steel. Use is made of carefully selected crystals of potassium permanganate which are reduced by boiling with hydrochloric acid; the manganous chloride so obtained is precipitated with sodium carbonate; the precipitate is converted into manganous-manganic oxide, and this is titrated with ferrous sulphate. It is recommended that the steel or iron should be dissolved in hydrochloric acid before oxidising with nitric acid to prevent the formation of organic compounds, which reduce permanganate.

Determination of Silicon.—F. W. Bauer § gives the results and indicates the methods adopted by several chemists for the analysis of ferrosilicon as follows :—

* *Zeitschrift für Angewandte Chemie*, 1899, pp. 1193-1194.

† *Engineering and Mining Journal*, vol. lxi. p. 263.

‡ *Journal of the Chemical Society*, vol. lxxviii. p. 50.

§ *Iron Age*, March 22, 1900, p. 3.

Number.	Silicon per Cent.	Method.
1	16.68	Volatilisation of silica by HF1 after solution and evaporation with HCl and HNO ₃ .
2	16.21	Direct fusion in Na ₂ O ₂ in nickel crucible.
3	16.19	Oxidation of silicon by Br in HCl solution.
4	15.90	Same as No. 3, and evaporation with silicon mixture.
5	15.80	No method given.
6	15.75	Direct fusion with Na ₂ CO ₃ .
7	15.75	Fusion with Na ₂ CO ₃ of residue from HCl solution.
8	15.71	Same as No. 6.
9	15.27	{ Fusion with Na ₂ CO ₃ of residue from HCl and HNO ₃ solution.
10	15.21	
11	14.90	
		Similar to No. 1.

Determination of Sulphur.—M. J. Moore* has experimented upon the effect of the physical conditions of the sample on the volumetric and gravimetric determination of the sulphur. A portion of the metal from the sample ladle was poured into a sand mould and another portion poured into water. The shot sample gave practically the same percentage in the gravimetric method, but much lower results with the volumetric determination. Some results are appended.

A. Riemer† draws attention to the inaccuracy and unsatisfactory character of the Wiborgh method for the determination of sulphur. Unfortunately, he observes, the inaccuracy is by no means so slight as it is stated to be in text-books, and whether the percentage of sulphur be high or low, it is in no case so unimportant as to admit of the process being applicable if a satisfactory result is to be obtained. The author gives the results obtained by this method and by check assays, using for these latter the oxidation method and bromo-hydrochloric acid, or ammoniacal hydrogen peroxide, or an iodine titration method which he describes. The results obtained were nearly always much too low in the case of the Wiborgh method. Thus a pig iron showing by the bromo-hydrochloric acid and titration method about 0.12 per cent. of sulphur, gave from 0.06 to 0.08 per cent. by the Wiborgh method, while a second with 0.09 per cent. of sulphur gave from 0.03 to 0.06 per cent. by the Wiborgh method. Even greater variations were observed in the case of ingot iron, as will be seen from the following table :—

* *Journal of the American Chemical Society*, vol. xxi. pp. 972-985.

† *Stahl und Eisen*, vol. xix. pp. 1064-1065.

	Percentage of Sulphur found by the		
	Hydrogen Peroxide Method.	Iodine Titration Method.	Wiborgh Method.
Ingot iron . . .	0·080	0·072	0·04
Ingot iron . . .	0·121	0·134	0·04
Ingot iron . . .	0·213	0·198	0·12
Pig iron	0·067	0·069	0·04
Pig iron	0·116	0·113	0·07
Pig iron	0·133	0·128	0·06
Pig iron	0·229	0·237	0·14

The iodine titration method is as follows—Weigh the sample into a flask of about 500 cubic centimetres capacity, with a glass or india-rubber stopper and a long thistle-funnel charging tube and a gas escape tube. Then dissolve in concentrated hydrochloric acid, adding this gradually by means of the thistle-funnel. The solution is then boiled, and when the operation is completely effected air is blown through. The gas is passed through wash-water, which gradually becomes warm and strongly acidulated. The sulphuretted hydrogen is caught in an ammoniacal solution of cadmium acetate. The author prefers this to other absorption solutions, as it is possible before titrating to make an estimate of the percentage of sulphur from the bulk of the cadmium sulphide. The absorption solution is placed in a narrow high cylinder, the absorption being then complete if the gas is passed through at not too rapid a rate. When the absorption is effected, a measured quantity of iodine solution is added, an excess being employed. Starch solution is next charged in and the whole acidulated. The sulphuretted hydrogen which is then evolved is acted on in the ordinary manner by the iodine in the solution, the excess of iodine subsequently remaining over being titrated back by sodium thiosulphate. The strength of the iodine solution should be such that one cubic centimetre of it shall be equivalent to 0·02 per cent. of sulphur. About 3 grammes is a useful quantity of the sample to take for the determination. The author does not consider a direct titration with iodine to be satisfactory, as acid having to be added in advance, a loss of sulphuretted hydrogen may ensue, while a red coloration also results, and this renders it difficult to determine the exact moment when the titration is complete. Any hydrocarbons that may be present scarcely affect the result, and need not be considered. The author considers this method to be preferable to any

other in which the sulphur is converted into sulphuretted hydrogen, being accurate as well as rapid.

Determination of Chromium.—R. W. Mahon * uses the following method for the determination of chromium in steel :—Dissolve 3 grammes of the sample in 50 cubic centimetres of concentrated hydrochloric acid in a 400 cubic centimetres lipped beaker, covering with a 5-inch watch-glass. Boil down until little more than a moist cake is left. Add 50 cubic centimetres of concentrated nitric acid, and boil for a few minutes, when the copious evolution of nitrous fumes will have largely ceased. When somewhat cooled, add 4 grammes of potassium chlorate and resume the boiling, continuing until the solution is reduced in volume to from 25 to 30 cubic centimetres. Dilute to 300 cubic centimetres with cold water, and add 15 cubic centimetres of ammonia of 0.90 sp. gr. Mix thoroughly by stirring, and filter the solution (first cooled if necessary) through a ribbed double paper, washing with cold water. Dilute the filtrate and washings to about 450 cubic centimetres, and titrate with standard solutions of ferrous ammonium sulphate and potassium permanganate. The most accurate and simplest way of standardising these solutions is by means of a standard solution of potassium bichromate. The results of experiments on the effect of filter-paper in this process show that it is negligible.

According to E. Döhler,† the sample is dissolved in hydrochloric acid, and from this solution the chromium is precipitated by repeated treatment with excess of barium carbonate in a closed flask. The precipitate is then fused in a porcelain crucible with potassium nitrate and potassium sodium carbonate, and the chromium estimated in the aqueous extract in the usual manner.

II.—ANALYSIS OF IRON ORES AND SLAG.

Determination of Phosphorus.—J. M. Camp ‡ gives a method of determining phosphorus in the presence of arsenic in ores, pig iron, and steel. Five grammes of the ground and dried sample are weighed

* *Journal of the American Chemical Society*, vol. xxi. pp. 1057-1060.

† *Chemiker Zeitung*, vol. xxiii. p. 868.

‡ *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xvi. pp. 57-58.

off into a 12-centimetre porcelain dish with watch-glass cover, 50 cubic centimetres of strong hydrochloric acid added, and the solution boiled gently for about thirty minutes. It is now diluted with sufficient cold water to prevent cutting the filter-paper, and filtered into another dish of the same size. This solution will contain all the arsenic in the ore not volatilised, and is placed on the steam-bath to go to dryness over-night. The residue is burned and fused with the mixed carbonates, and the fusion allowed to harden around a platinum rod. The crucible is now warmed, and the greater bulk of the fusion removed on a platinum rod. This, while still hot, is placed in the dish with cover in which the ore was originally dissolved, and containing 10 or 15 cubic centimetres of water. Dilute hydrochloric acid is added to the crucible and warmed, and this process is repeated until all signs of the fusion are removed, and added to the dish containing the fusion. An excess of strong hydrochloric is now added to dissolve any of the remaining fusion, and this dish is placed with the other on the sand-bath.

In the morning, to the dish containing the dried mass from the original filtrate 2 grammes of pure oxalic acid are added and 50 cubic centimetres of strong hydrochloric acid, and the solution with watch-glass cover evaporated to dryness by hard boiling, but not baked. When cool, add 30 cubic centimetres strong hydrochloric acid, and evaporate to first appearance of insoluble ferric chloride. Add 10 cubic centimetres strong nitric acid when the violent action has ceased. Warm until all is in solution, dilute with cold water and filter into a 16-ounce flask, using 2 per cent. nitric acid for washing. In the meantime to the dish containing the fusion dilute hydrochloric acid is added just sufficient to moisten, and enough hot water to dissolve the chlorides. This is warmed until all is in solution but the separated silica, and filtered into the same flask with the original filtrate. The phosphorus is now precipitated by the molybdate method.

Determination of Silica in Chrome Ore.—According to George Tate,* ferro-chromium or chrome ore (1–2 grammes) is fused with about five times its weight of sodium peroxide in a nickel crucible, and when cold immersed in water in a nickel dish, neutralised with hydrochloric acid, and evaporated to dryness. The residue is heated with 40 cubic centimetres of strong sulphuric acid until fumes of sulphuric acid appear. When cool, it is treated cautiously with water, transferred to a porcelain

* *Journal of the Chemical Society*, vol. lxxviii. p. 313.

dish, made up to about a quarter litre, boiled to dissolve the sulphates, and the residual silica is washed, dried, ignited, and weighed. If coloured, it is evaporated with hydrofluoric acid and a drop of sulphuric acid, and any residue weighed and deducted.

Determination of Alumina.—J. M. Camp * gives the following method for determining alumina as phosphate in ores and slag. The method as used on ore and slag is as follows:—To the cold hydrochloric acid filtrate from the solution of 1 gramme of ore or slag, diluted to about 400 cubic centimetres, in a No. 5 beaker, add 30 cubic centimetres of a 10 per cent. solution of ammonium phosphate, and then ammonia until a faint permanent precipitate is formed. 1.5 cubic centimetre of strong hydrochloric acid is now added, and for ores, on account of the greater bulk of iron present, 50 cubic centimetres, and for slags 30 cubic centimetres of a 20 per cent. solution of sodium hyposulphite. The beaker is now heated just to boiling. Eight cubic centimetres of strong acetic acid and 15 cubic centimetres of a 20 per cent. solution of ammonium acetate are added to the boiling solution and boiled ten minutes. If the latter is added before the solution is boiling or near the boiling-point, the precipitate will be flocculent and difficult to filter. Decant the clear solution and wash precipitate on to the filter, and then wash ten times with hot water. Transfer the precipitate to a platinum crucible without lid, and place in front part of the muffle. When the paper is charred, transfer to the hottest part of the muffle till burned. Cool and weigh. 41.85 per cent. of the weight is alumina.

Slag Analysis.—T. Ulke † gives the following method for the rapid determination of lime in slag:—Dissolve a half gramme of the powdered sample in 6 cubic centimetres of nitric acid and 30 cubic centimetres of hot water; dilute to 150 cubic centimetres, add a drop of sulphuric acid to precipitate barium, and boil; then nearly neutralise with ammonia, and add three grammes of ammonium oxalate, and boil for a few minutes. Calcium oxalate is precipitated in a granular condition, silica and iron remaining in solution. The precipitate is filtered off, and the lime determined by titration with potassium permanganate. The time required is fifteen to twenty minutes.

* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xvi. pp. 59-60.

† *Engineering and Mining Journal*, vol. lxi. p. 164.

According to A. D. Herzfelder,* the assimilable phosphoric acid contained in basic slag is in the form of tricalcium phosphate. The slag also contains calcium phosphate of higher basicity, iron phosphates, iron silico-phosphates, calcium silico-phosphates, calcium oxide and carbonate, silicon chiefly in combination with calcium, iron oxide, sulphide, and carbonate, &c.

The difficulties in the way of determining the tricalcium phosphate by extraction with citric acid are the presence of lime, which neutralises some of the acid, and the solution of a portion of the silicate, most of which is precipitated with the molybdate, redissolves in ammonia, and is again precipitated by the magnesia mixture. In this way 0.01 and 0.02 gramme of SiO_2 will cause an error of 0.6 and 1.27 per cent. in the phosphoric acid. This source of error, and the error (in the other direction) caused by the presence of lime, can be avoided by altering the process, but the presence of iron in the slag involves another difficulty, since iron compounds diminish the solubility of tricalcium phosphate in citric acid.

It is concluded that the error of the Wagner method is as much as 2–3 per cent., and varies according to the nature of the slag. With slags which do not contain much total phosphoric acid and silica, relatively little soluble phosphoric acid, but much lime and iron, the results will be too low, whilst with slags which contain much phosphoric acid (both total and soluble) and silica but only a little lime and iron, the results for soluble phosphoric acid may be even higher than the total phosphoric acid.

According to C. Aschman,† the following solutions are required:—Nitro-sulphuric acid, made by taking 420 grammes of nitric acid of specific gravity 1.2, and 50 grammes of strong sulphuric acid, and diluting with water to 10 litres. Solution of citric acid, made by dissolving 500 grammes of the acid to 1 litre. Wagner's magnesia mixture, made by dissolving 110 grammes of crystallised magnesium chloride, and 140 grammes of ammonium chloride in 700 cubic centimetres of ammonia (of 8 per cent. strength), and 1300 cubic centimetres of water. Molybdate solution, made by dissolving 150 grammes of ammonium molybdate and 400 grammes of ammonium nitrate to 1 litre, and pouring the solution into a litre of nitric acid of specific gravity 1.19.

Five grammes of the sample are put into a half-litre shaking bottle, which is then filled up to the mark with nitro-sulphuric acid. After

* *Journal of the Chemical Society*, vol. lxxvi. p. 808.

† *Ibid.*, pp. 807–808.

rotating for half-an-hour in a Wagner apparatus, the liquid is left overnight. Fifty cubic centimetres of the filtrate are then mixed with 10 cubic centimetres of citric acid solution, and neutralised with ammonia; 50 cubic centimetres more water are added, and the whole left to cool twenty minutes. To the liquid, which must be perfectly clear, are now added 20 cubic centimetres of magnesia mixture; after a few hours' standing with frequent stirring, the magnesium phosphate precipitate is collected as usual.

If the neutralised liquid deposits silicic acid, another portion of the acid solution must be precipitated with molybdate in the usual manner.

Franz W. Dafert * states that the valuation of basic slags by their citrate solubility cannot be considered a scientific method, as it depends too much on the personal equation of the operator.

A. Casali† deals with the use of citric acid for extracting the soluble phosphate from basic slag, which gives a much higher result than that obtained with the ammonium citrate more usually employed. In reporting the result of analyses, it should always be stated which reagent has been used.

III.—FUEL ANALYSIS.

Coal Analysis.—Great attention is being devoted in the United States to the subject of coal analysis. The recommendations of a committee on the subject are summarised.‡ When estimating the sulphur, it is advisable to avoid the use of coal-gas. If an ultimate analysis is thought desirable, the sample should be burnt with lead chromate, so as to retain the sulphur.

In a note on the chemical composition of coal, E. Lecocq§ considers that the bromine test will afford a convenient and rapid means of ascertaining the tendency of a coal to undergo spontaneous combustion.

R. K. Meade and J. C. Attix|| discuss the determination of volatile combustible matter in coke and anthracite coal, and show how the size of the sample, of the crucible in which it is heated, the tightness of the

* *Journal of the Chemical Society*, vol. lxxviii. p. 167.

† *Ibid.*, vol. lxxviii. p. 311.

‡ *Journal of the American Chemical Society*, vol. xxi. pp. 1116-1132.

§ *Bulletin de l'Association Belge des Chimistes, Colliery Guardian*, vol. lxxix. p. 20.

|| *Journal of the American Chemical Society*, vol. xxi. pp. 1137-1145.

lid, the method of heating, and other factors, are the cause of many discrepancies in the returns of different chemists. Uniform heating in a current of nitrogen or of hydrogen was used as a standard, and the following method is adopted:—After heating a sample of coke or anthracite over a blast-lamp and burner for, say, seven minutes and weighing, it is again heated over the same burners and for the same length of time. The second heating gives an approximation of the amount of carbon burned in the first, if the conditions of heating are the same. If the loss, therefore, from the second heating is deducted from that of the first, the difference agrees fairly closely with the loss obtained by heating in nitrogen or hydrogen.

Determination of Moisture.—In comparing various methods for this purpose, E. van der Bellen * finds that the capacity of coal for absorbing oxygen at temperatures ranging from the ordinary to above 100° C. is a factor that should be taken into consideration in moisture determinations. He obtained the following instructive results from different portions of the same sample :—

	Water per Cent.
By exposure during seven days in a desiccator containing H_2SO_4	6·85—6·95
After heating four hours on the water-bath at 97° C.	6·48—6·35
By heating to 110° C. in a drying oven for twenty-four hours	4·54—4·56
By direct weighing, the moisture being absorbed in a calcium chloride tube	7·31—7·42

the latter method being the most accurate, though the apparatus is rather troublesome.

Determination of Phosphorus.—J. M. Camp † gives the following process for the determination of phosphorus in coke and coal. The coke, ground to pass a 40-mesh sieve, is dried at 100° C. for an hour, and 5 grammes are weighed into a 1½-inch porcelain crucible, which is left in a muffle over-night. The ash is transferred to a platinum crucible and 5 cubic centimetres of dilute hydrochloric acid and 10 cubic centimetres of hydrofluoric acid are added and heated, but not allowed to boil. In twenty to thirty minutes the solution is dried, but not baked. Then 15 cubic centimetres of the same dilute hydrochloric acid (one part of acid to two of water) is added, and the crucible warmed

* *Protokol des St. Petersburg Polytechn. Vereins.*

† *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xvi. pp. 55–57.
1900.—i.

until all is in solution, which is transferred to a porcelain dish and 5 cubic centimetres of strong nitric acid is added. The solution, amounting to about 75 cubic centimetres, is boiled for one or two minutes, and filtered free from silica and carbon, and the phosphorus determined in it by molybdate. The treatment for coal is similar, only that the coal is first coked in a large platinum crucible, and then transferred to the porcelain crucible for combustion.

The Use of Röntgen Rays in Fuel Examination.—F. Kotte * observes that Röntgen rays do not penetrate all substances, and while they pass through coal, the mineral constituents the coal contains offer a greater or lesser degree of resistance to their passage, their resistance being naturally greater the thicker the layers in which they occur. It is therefore possible to obtain a knowledge of the extent to which they occur in coal by means of a Röntgen ray photograph. Not only thick layers of shale can be detected in this manner, but even scattered pieces of shale and also of pyrites. This was pointed out by Thörner in 1897, and more recently and completely by H. Couriot. J. Daniel has also considered this question, and the author has himself made a series of tests of various kinds of fuel from turf to coke. He describes the method of making the experiments, and gives numerous illustrations of the results obtained. To obtain anything like an accurate idea as to the percentage of ash, it is necessary that the material should be in the form of powder. It is not possible always to obtain accurate results even in this way, however, for the experiments showed that different samples of coal from the same seam often show very different degrees of resistance to the Röntgen rays. The general conclusion to which the author has arrived, and which is borne out by the results of other experiments to which he refers, is that the value of the Röntgen rays in the examination of fuel is not of that practical value that has been claimed for them. These later experiments, to which the author refers, were made at Sulzbach in the Saarbrücken district, and the results obtained showed that it was quite impossible to even make a rough idea as to the percentage of ash in the fuel from an examination of the photograph obtained by use of the Röntgen rays.

Determination of Sulphur in Bitumens.—A. C. Langmuir † criticises the process recommended by S. F. and H. E. Peckham, and points out several sources of error. No precautions are taken to prevent

* *Stahl und Eisen*, vol. xix. pp. 1017–1020 ; 29 illustrations.

† *Journal of the American Chemical Society*, vol. xxii. pp. 99–102.

absorption of sulphur compounds during the fusion with alkali nitrate and the subsequent slow evaporation of the dissolved mass with hydrochloric acid. The most serious objection is that on precipitating the iron and aluminium by means of ammonia, and expelling the excess of the latter by boiling, a portion of the sulphuric acid recombines with the iron. Finally, if the sulphuric acid is precipitated after removing the calcium with ammonium oxalate, there is a danger of obtaining a very impure barium sulphate, which is rendered still more probable by the presence of a large quantity of alkali chlorides.

Eschka's process, as described by Heath, is admittedly the best process for the estimation of sulphur in bituminous coals.

For the estimation of sulphur in petroleum, according to Siegfried Friedländer,* the sample is burnt in an Ohlmüller lamp, which is weighed before and after the experiment, the products of combustion being drawn through two wash-bottles containing a 5 per cent. solution of potassium hydrogen carbonate. The solution is then oxidised by means of potassium permanganate and hydrochloric acid, and the sulphuric acid estimated as usual. Equally good results are obtained by the use of the apparatus and processes of Hensler, Engler, Kiessling, or Ohlmüller, but the latter is by far the quickest, it being possible to effect an analysis in half an hour. Attention is called to the occasional presence of sulphur compounds in the air, and to the means of removing them.

For the estimation of sulphur in naphtha, according to Alexander P. Lidoff,† 1 gramme of the sample is dissolved in ether and carefully mixed with 30 grammes of a mixture of 17 parts of potassium nitrate and 13 parts of sodium carbonate. When the ether has completely evaporated, the mixture is put, by small degrees, into a platinum dish heated to redness. The fused mass contains the sulphur as sulphate, which is then estimated in the usual way.

IV.—GAS ANALYSIS.

Apparatus for the Analysis of Fuel Gases.—George E. Thomas‡ deals with this apparatus for technical work. It consists essentially of a burette and levelling tube joined by rubber

* *Journal of the Chemical Society*, vol. lxxviii. p. 107.

† *Ibid.*, p. 107.

‡ *Journal of the American Chemical Society*, vol. xxi. pp. 1108–1112.

and capillary glass tubes to a series of absorbing bottles, filled with aqueous caustic potash, bromine water, and phosphorus covered with water; another bottle is filled with water only, and it is only used for storing gas. There is also the usual arrangement for exploding mixtures of gas and air. The water in the burette is acidified with sulphuric acid, so as to diminish the solubility of carbon dioxide.

STATISTICS.

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I.—UNITED KINGDOM.

Mineral Statistics.—According to the official report of Her Majesty's Inspectors of Mines,* the production of coal in the United Kingdom in 1899 amounted to 220,085,368 tons. The production during the previous year was 202,042,243 tons. There were employed at mines under the Coal Mines Inspection Acts 706,894 persons.

The British production of iron ores under the Coal and the Metalliferous Mines Acts was :—

	Tons.
Coal Mines Act	7,775,868
Metalliferous Mines Acts	1,956,796
Total	9,732,664

In a presidential address, G. Beard † traces the progress of the iron and steel industries of Great Britain from a statistical point of view, and makes comparisons with the productions of other countries.

* *Mines and Quarries: General Report and Statistics for 1899, Part I.*

† *Journal of the West of Scotland Iron and Steel Institute*, vol. vii. pp. 3-18.

Iron Trade Statistics.—The British Iron Trade Association reports* the production of iron and steel in the United Kingdom in 1899 to have been as follows:—

	Tons.
Total pig iron	9,393,018
Wrought iron	1,201,606
Bessemer steel ingots	1,825,074
" " acid	1,307,696
" " basic	517,378
" " rails	838,148
Open-hearth steel ingots, acid	2,735,563
" " basic	294,688

There were in operation 408 blast-furnaces, 41 acid Bessemer converters, and 24 basic Bessemer converters.

Blast-Furnace Statistics.—The following table shows the condition of the blast-furnaces in Great Britain at December 31, 1899.†

District.	Number of Furnaces in Blast, Dec. 31, 1899.	Average Output per Week.	Out of Blast, Dec. 31, 1899.	Building or Re- building.	Number of Furnaces in Blast, March 31, 1900.
		Tons.			
Cleveland	66 }	60,828	{ 15	7	65
Durham	29 }		{ 12	9	29
Scotland	84	23,862	16	5	81
West Cumberland	30	17,901	13	10	28
Lancashire	24	16,225	15	3	24
South Wales	27	17,334	39	9	27
South Staffordshire	21	8,257 }	52	15	{ 22
North Staffordshire	20	6,069 }			{ 20
Derbyshire	33	8,320	8	3	33
Lincolnshire	15	6,832	7	2	16
Northamptonshire	15	4,920	6	...	15
Notts and Leicestershire	16	5,250	1	...	16
Shropshire	4	1,000	5	...	4
South and West Yorkshire	19	5,508	8	2	19
North Wales	4 }	1,564	4	0	{ 4
Other Districts	1 }				{ 1
Totals	408	183,870	201	65	404

Open-Hearth Furnaces.—A list ‡ of British open-hearth steel-works and of open-hearth furnaces in and out of work at December 31,

* *Iron and Coal Trades Review*, vol. ix. pp. 607-608.

† Supplement to the *Iron and Coal Trades Review*, January 12, 1900.

‡ *Ibid.*, March 30, 1900.

1899, shows that there were 73 works employing $441\frac{1}{2}$ furnaces. They were distributed as follows :—

District.	In.		Out.		Total.		Building.	
	Acid.	Basic.	Acid.	Basic.	Acid.	Basic.	Acid.	Basic.
Scotland	98	1	17	...	115	1	2	...
Sheffield and Leeds	43 $\frac{3}{4}$	5	4 $\frac{1}{2}$	...	48	5	...	2
North and South Wales	76 $\frac{1}{2}$	8	9 $\frac{1}{2}$	1	86	9	4	...
Lancashire and Cheshire	21 $\frac{1}{2}$	5	4	1	25 $\frac{1}{2}$	6	1	...
North-East Coast	94 $\frac{1}{2}$	3	14 $\frac{1}{2}$	1	109	4	4	4
Staffordshire	7	22	1	3	8	25	...	...

Imports and Exports.—According to the Board of Trade Returns, the exports from the United Kingdom during 1899 were as follows :—

	Tons.
Pig iron	1,379,296
Hoops, sheets, and plates	110,013
Bar, angle, bolt, and rod	159,133
Railroad iron	591,797
Wire	49,253
Tin plates	256,629
Cast and wrought	358,125
Old iron	116,400
Unwrought steel	328,580
Steel and iron manufactures	44,470

The imports were as follows :—

	Tons.
Iron ore	7,055,178
Bar, angle, bolt, and rod	73,156
Unwrought steel	77,290
Girders, beams, and pillars	95,476
Unenumerated	225,255

Scarcity of Coal.—W. S. Barrett's presidential address to the Manchester Geological Society dealt with the present conditions of the coal industry and the future supply of coal. The scarcity of coal is also dealt with by Bennett H. Brough* and by E. Lozé†

* *Nineteenth Century*, 1900, pp. 663-668.

† *Les Charbons Britanniques et leur Epuisement*. Paris, 1900.

II.—*AUSTRALASIA.*

Coal-Mining in Queensland.—According to the Annual Report of the Under-Secretary for Mines for the year 1898, the output of coal was 407,934 tons, and the number of persons engaged in coal-mining was 1278. The Report also notes that 67 tons of manganese ore, valued at £251, was raised.

Coal-Mining in Tasmania.—According to the Report of the Secretary of Mines, the output of coal in Tasmania during the financial year 1898–99 was 44,141 tons. There were eighteen deaths from accidents, or 2·91 per 1000 persons employed.

Mineral Statistics of Victoria.—The output of coal in Victoria is given as 262,380 tons in 1899, as compared with 242,859 tons in the previous year. The total output up to date is 1,526,937 tons.*

Mineral Statistics of New Zealand.—According to the Minister of Mines,† the output of coal in New Zealand in 1898 was 907,033 tons, 2003 persons being employed. The production of manganese ore was 217 tons, valued at £703.

III.—*AUSTRIA-HUNGARY.*

Iron Trade Statistics.—Official statistics ‡ show the production of Austria in 1898 to have included the following:—

	In 1898.	As Compared with Previous Year.	
		Increase.	Decrease.
	Metric Tons.	Per Cent.	Per Cent.
Iron ore	1,733,649	7·42	...
Manganese ore	6,132	2·00	...
Coal	10,947,522	4·33	...
Brown coal	21,083,361	3·06	...
Graphite	33,062	...	14·13
Asphalt rock	643	114·33	...
Forge pig iron	837,767	9·84	...
Foundry pig iron	120,070	...	4·14
Brown coal briquettes	57,474	0·52	...
Coal briquettes	62,483	...	8·57
Coke	1,068,141	15·31	...

* *Annual Report of the Secretary of Mines*, Melbourne, 1900.

† *New Zealand Mines Statement*, Wellington, 1899.

‡ *Statistisches Jahrbuch des k.k. Ackerbauministeriums*, Part II., Vienna, 1899; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 621–624.

The quantity of nickel speisse and nickel salts produced in Austria in 1898 amounted to 48 tons, and of wolfram 36 tons was raised during the year.

The production of iron ore and of pig iron was as follows in the different divisions of the Empire :—

	Iron Ore.	Forge Pig Iron.	Foundry Pig Iron.	Total Pig Iron Production.
	Metric Tons.	Metric Tons.	Metric Tons.	Per Cent.
Bohemia	633,278	243,386	15,463	27·02
Lower Austria . . . . .	...	52,139	7,832	6·26
Salzburg	7,648	...	1,609	0·17
Moravia	10,915	200,106	78,242	29·06
Silesia . . . . .	...	41,787	11,497	5·56
Styria	1,005,385	220,633	1,461	23·19
Carinthia	66,400	29,687	1,509	3·26
Tyrol	6,412	990	769	0·18
Carniola	3,606	2,247	...	0·23
Trieste . . . . .	...	46,794	...	4·89
Galicia	4	...	1,687	0·18
Totals	1,733,648	837,769	120,069	10·000

As far as pig iron is concerned, all the States show an increase as compared with the production in 1897, with the exception of Salzburg, Carniola, and Galicia.

There were in Austria in 1898, 5323 workpeople employed at iron ore mines and 6168 at ironworks, this being an increase of 54 at the mines and a diminution of 478 at the works. There were in all 82 iron blast-furnaces, a diminution of 7 as compared with the number of furnaces existing in 1897, and of these 53 were in blast for 2416 weeks. In 1897, 51 were in blast for 2377 weeks. The number of workpeople employed in brown coal mining was 49,690, the average production per workman employed being 424·3 tons. Of the total quantity of brown coal produced during 1898, some 82 per cent. was mined in Bohemia and 12 per cent. in Styria.*

Of the total quantity of coal produced in Austria in 1898, 41·55 per cent. was mined in Silesia and 36·94 per cent. in Bohemia. More coke was, however, produced in Moravia than in Silesia.†

A table is published by M. Caspaar ‡ showing the production, im-

* *Statistisches Jahrbuch des k.k. Ackerbauministeriums*, Part II., Vienna, 1899; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 636.

† *Ibid.*, p. 650.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 542-543.

port, export, and consumption of pig iron in Austria, together with the price of Scotch pig iron, for each of the years 1849 to 1898, so far as statistics are available. The table also shows the imports and exports of finished iron wares of Austria during the period in question.

Mineral Statistics of Hungary.—Details are given * as to the extent of the areas devoted to the different mining industries in Hungary in 1898, and to the appliances in use at the mines. Of the total area of the various mining concessions, 58·4 per cent. was devoted to coal-mining, and 17·7 per cent. to ironstone mining. Of iron blast-furnaces there were 66 in 1898, as compared with 69 in 1897 and 63 in 1896. They were divided as follows among the various mining districts :—

Neusohl	1
Buda-Pest . . . . .	...
Nagybánya	6
Oravicza	11
Szepes-Igló	38
Zalatna	7
Agram	3
	<hr/> 66

The collieries possessed 56 fans, as compared with 45 in 1897 and 32 in 1896. They possessed no electric rock-drills, but the ironstone mines had 68 of these in 1898 and 58 in 1897.

The number of workpeople employed at the iron ore mines was 10,109 men, 382 women, and 1292 children. In collieries 8315 men, 404 women, and 862 children, and in brown coal mines 19,341 men, 359 women, and 934 children found occupation.

The official Hungarian mineral statistics for 1898 have been published. The production comprised 4,206,694 tons of brown coal, 1,239,498 tons of coal, 31,781 tons of briquettes, 8190 tons of coke, 439,404 tons of pig iron, 499,785 tons of iron ore exported, and 8028 tons of manganese ore.

The total number of coke-ovens was 172 and there were 3 briquette presses, as compared with the same number of coke-ovens but with 4 presses in the previous year. The coal-screening plants numbered 23, an increase of 1 on the year. Of iron blast-furnaces there were 66 in 1898 as compared with 69 in 1897. Of these, 38

* *Bányászati és Kohászati lapok*, 1899; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 128-130, 142-144.

were in the Szepes-Igló mining district, 11 in that of Oravicza, and 7 in that of Zalatna.*

Imports and Exports.—The imports into Austria-Hungary in 1899 included :—

	Tons.
Coal	5,297,330
Brown coal	19,534
Coke	564,005
Iron ore	212,412
Manganese ore	5,855

The exports included :—

	Tons.
Coal	1,879,456
Brown coal	8,662,657
Coke	252,940
Iron ore	326,833
Manganese ore	1,127

Brown Coal in Bohemia.—In 1899 the districts of Teplitz, Brüx, and Komotau, in Bohemia, produced 15,576,440 tons of brown coal. There were 94 collieries in operation, and 25,561 miners were employed.

Technical Education.—New regulations common to the Schools of Mines of Leoben and Przibram have been promulgated by the Austrian Government.† The course covers two years for general sciences, and one year more for mining or for metallurgy.

IV.—BELGIUM.

Mineral Statistics.—The mineral production of Belgium included the following in 1898 : ‡—

	Metric Tons.
Coal	22,088,335
Iron ore	217,370
Manganese ore	16,440
Foundry pig iron	93,645
Forge pig iron	308,875
Ferro-manganese	6,259
Bessemer pig iron	173,085
Basic pig iron	397,891
Finished iron manufactures :—	
Sheets	91,686
Other kinds	393,354
Finished steel manufactures	567,728

* *Bányászati és Kohászati lapok*, 1899; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 128-130.

† *Montan Zeitung*, November 18, 1899.

‡ *Annales des Mines de Belgique*, vol. iv. No. 4.

Coal was produced at 257 collieries employing 122,846 workpeople. The average thickness of the coal seams worked was about two feet, and the average working depth 1430 feet. The production of coal increased by 595,889 tons as compared with the production in the previous year, and is the maximum output ever produced in Belgium; 9·3 per cent. of the output was consumed at the collieries themselves. The first cost was 9·95 francs per ton, and the average net earnings of a workman was 1080 francs. The out-turn per workman employed was 180 tons, or 245 tons per miner, or 980 tons per man at the working face.

There were seventeen strikes during the year 1898, which led to a loss of 27,000 working days. The accidents in collieries numbered 319, 172 deaths resulting, while in smelting works there were 58 accidents which resulted in 25 deaths.

The Belgian official returns show that in the first half of 1899 there were 113 collieries in operation, the production of coal having been 10,420,410 tons. The ironworks produced during the same period 502,285 tons of pig iron, 250,730 tons of wrought iron, and 359,170 tons of steel ingots.

In 1899 in Belgium there were 113 collieries in operation, the total production being 21,917,740 tons. The metallurgical production included 1,036,185 tons of pig iron, 489,480 tons of wrought iron, 729,920 tons of steel ingots, and 621,020 tons of forged steel.*

The *Annuaire Statistique de la Belgique*, issued by the Minister of the Interior, contains the definite mineral statistics for 1897. There were in that year in operation in Belgium 1523 quarries, employing 32,601 men, and raising mineral worth 48,904,276 francs. The production of the metal mines included :—

	Quantity. Tons.	Value. Francs.
Iron ore	240,774	1,264,510
Manganese ore	28,372	342,700

There were 1934 miners employed in the metal mines, the mean daily wage being 2·68 francs. Of coal, 21,492,446 tons were raised from 117 collieries, 120,382 workpeople being employed. The mean yearly wage was 1006 francs, and the average output per person employed, 179 tons.

* *Annales des Mines de Belgique*, vol. v. p. 166.

V.—CANADA.

Mineral Statistics.—The Canadian Geological Survey give the following productions for 1899 : *—

Iron ore, tons	77,158
Coal, tons	4,565,993
Coke, tons	100,820
Petroleum, barrels	808,570
Nickel ore, lbs.	5,744,000

The Report of the Bureau of Mines shows that the mineral production of Ontario in 1899 included—

	Tons.
Iron ore	27,409
Pig iron	48,253

together with 26,978,977 gallons of petroleum and 301,600 dollars' worth of natural gas.

Early in 1896 the new blast-furnace at Hamilton was blown in, and from that time until the end of 1898 it smelted 165,653 tons of ore and 19,847 tons of mill-cinder, and produced 100,566 tons of pig iron. Last year it smelted 77,023 tons of ore and 8614 tons of scale of mill-cinder, and produced 48,253 tons of pig iron. The proportion of Ontario ores used in the furnace in 1899 was 27 per cent. of the whole, being 20,968 tons, whereas in 1897 it was only 8 per cent. Two mining companies, whose operations were carried on chiefly in Hastings County, raised during the year 27,400 tons, nearly all of which was shipped to Hamilton. The company is now about to establish steelworks in connection with its blast-furnace. On January 25 of the present year a new charcoal-furnace erected at Deseronto was blown in, and for the first half of the year the two furnaces have produced 30,090 tons of pig iron, valued at 409,158 dollars, having smelted 14,452 tons Ontario ores, 35,510 tons foreign ores, and 5135 tons mill-cinder. The quantity of iron ore mined in the Province during the first half of the present year has been 10,788 tons.

The Mining Industry of Newfoundland.—According to a return furnished by J. P. Howley, Director of the Geological Survey of Newfoundland, the production of iron ore in that Colony during 1898 amounted to 102,000 tons, against 58,940 tons in the previous year. The production of coal was 2900 tons. Newfoundland is not embraced in the Dominion of Canada.

* *Iron Age*, March 22, 1900, p. 15.

VI.—CHINA.

The Trade of Shanghai.—The imports into Shanghai included, in the years named : *—

	1897.		1898.	
	Weight in Pikuls.†	Value in Haik-Taels.	Weight in Pikuls.	Value in Haik-Taels.
Nail rod	129,782	343,921	286,609	759,515
Bar iron	77,835	212,491	142,397	391,591
Sheets	31,927	95,780	39,369	118,108
Galvanised sheets	27,567	139,148	35,097	183,466
Iron wire	22,963	137,779	31,158	171,367
Wire rod	25,802	58,054	47,929	119,823
Pig iron	31,078	74,587	154,693	371,263
Scrap iron	141,866	271,923	226,460	490,253
Bar steel	30,572	152,859	31,042	155,212
Mild steel	18,665	45,360	159,694	352,181

The imports from the United States are increasing rapidly.

VII.—FRANCE.

Mineral Statistics.—Returns of the mineral production‡ of France for 1899 give the output of coal at 32,933,788 metric tons, an increase of 577,684 tons on 1898. That of pig iron rose from 2,525,075 metric tons to 2,567,388 tons, a gain of 42,313 tons. The production of wrought iron was 842,755 tons, an increase of 76,345 tons. That of manufactured steel increased from 1,174,075 tons to 1,253,701 tons, and of Bessemer and open-hearth ingots from 1,433,717 tons to 1,529,182 tons.

The output of finished steel in France during the six months ending with June 1899, as compared with the first half of 1898, is shown below :—

	First Six Months.	
	1899. Tons.	1898. Tons.
Bars	345,148	330,061
Rails	128,698	112,001
Plates	155,373	120,879
Totals	629,219	562,941

* *Deutsches Handelsarchiv*, through *Stahl und Eisen*, vol. xix. p. 1088.

† A pikul is about equal to 133½ lbs.

‡ *Comité des Forges*, Bulletin No. 1576.

The *Journal Officiel* publishes a report on the French mining industry in 1898, drawn up by a commission appointed to collate the available statistics. The production of mineral fuel comprised 30,172,000 tons of coal, 1,654,000 tons of anthracite, and 530,000 tons of lignite. The colliery consumption amounted to 2,173,000 tons. The number of miners employed was 148,600.

Coal.—Attention is directed * to the increased consumption of coal in France. In 1899 the consumption amounted to 45,600,000 tons, the production being 33,300,000 tons, and the imports 12,610,000 tons. *In 1898 the consumption was distributed in the following manner:—

	Tons.	Per Cent.
Mines	2,860,000	6·49
Metallurgy	7,757,000	17·95
Industrial machinery	8,643,000	19·96
Railway	5,105,000	11·80
Sea navigation	425,000	0·99
Inland navigation	37,000	0·09
Works, household, &c.	18,468,000	42·70

A recently issued French Government Report gives the statistics and other particulars relating to the employment of women and children in or about mines and quarries in France. Details for the year 1898 are given. The total number of mines and quarries of all sorts, whether worked permanently or temporarily, amounted to 40,331, employing 297,787 workpeople, of whom 33,687, or 11·3 per cent., were women and children.

In 1899 the two coalfields of the Pas-de-Calais and the Nord produced together 20,533,671 tons from 124 pits. The Pas-de-Calais produced 14,501,603 tons from 77 pits. The outputs of the largest collieries were as follows:—

	Tons.
Lens	3,065,611
Courrières	1,930,868
Brûay	1,624,331
Bully-Grenay	1,486,303
Noeux	1,335,562
Liévin	1,153,512
Marles	1,127,465
Dourges	1,044,240

In the Nord coalfield the most productive collieries were—

	Tons.
Anzin	3,154,000
Aniche	1,157,412
Escarpelle	724,383

* *Revue Scientifique*, vol. xiii. p. 510.

Coke.—The production of coke in France in 1898 * amounted to 1,949,735 tons, as compared with 1,843,085 tons in 1897. The different coalfields participated in this production as shown in the following table :—

	1898. Tons.
Nord and Pas-de-Calais	1,357,384
Saône-et-Loire and Ronchamp	158,735
Bourbonnais and Auvergne	90,202
Loire	113,393
Gard	118,818
Hérault	2,960
Tarn and Aveyron	110,889

The principal collieries producing coke were as follows :—

	1898. Tons.
Lens	350,825
Anzin	299,319
Aniche	174,211
Douchy	136,950
L'Escarpelle	115,310
Noeux	101,500
Dourges	82,171
Carmaux	63,434
St. Etienne	51,800

Iron Trade Imports and Exports.—The iron trade imports and exports of France in 1899 are stated to have included : †—

	Imports.		Exports.	
	1898.	1899.	1898.	1899.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Coke	1,374,590	1,428,610	62,180	63,970
Iron ore	2,032,240	1,950,665	236,169	291,346
Pig iron	62,440	96,638	161,431	153,792
Ferro-manganese and ferro-silicon	3,485	4,454	350	220
Ferro-aluminium . . . . .	...	...	1	...
Weld iron	22,012	32,850	52,031	53,181
Ingot iron	6,352	11,576	47,562	34,148
Filings, &c.	1,460	1,022	4,002	2,513
Scrap	21,910	29,741	24,494	44,400
Cinder	34,075	36,327	307,273	303,605

The total imports of all kinds of pig iron, weld iron, and ingot metal amounted to 217,937 tons in 1898, and to 268,403 tons in 1899, an increase of over 23 per cent. The total similar exports were 373,124

* *Echo des Mines*, vol. xxvi. pp. 6061-6062.

† *Comité des Forges de France*, Bulletin No. 1553.

tons in 1898 and 349,976 tons in 1899, a diminution of about 6·2 per cent.

Technical Education.—A lengthy account, covering 180 pages, of the history and programme of the Saint-Etienne School of Mines, has been published.*

VIII.—GERMANY.

Mineral Statistics.—The final official statistics of the German Empire for 1898, which have recently been issued, show that the mineral production included :—

	Metric Tons.
Coal	96,309,652
Brown coal	31,648,898
Iron ores	15,901,263

In Germany in 1898 pig iron was produced at 101 works with 225 furnaces in blast, the production amounting to 6,366,900 tons. The average number of persons employed in the iron industry was as follows :—

Iron mines	32,672
Blast-furnaces	27,746
Foundries	85,152
Forges	38,135
Steelworks	104,819
Total	288,524

Iron Trade Statistics.—H. Rentzsch † has collected from German official statistics details relating to the production of iron and steel, and their manufacture in Germany, including Luxemburg, in the periods 1896–98, and, in some cases, 1889–98. From these the following data are taken :—

Production of Iron Ore.

	1896.	1897.	1898.
Active mines	542	586	550
Iron ore raised, metric tons	14,162,335	15,465,979	15,901,263
Value per ton, shillings . .	3·62	3·88	3·82
Workpeople employed . .	35,223	37,991	38,320

* *Bulletin de la Société de l'Industrie Minérale*, 1900, No. I.

† *Stahl und Eisen*, vol. xx. pp. 39–43.

Production of Pig Iron.

	1896.	1897.	1898.
Producing works	106	109	109
Charcoal pig iron, metric tons	16,385	16,509	10,202
Coke and mixed fuel, pig iron, metric tons	6,356,190	6,864,957	7,302,564
Total pig iron, metric tons	6,372,575	6,881,466	7,312,766
Value per ton, shillings	47·02	50·88	51·79
Ores and slags smelted, metric tons	15,892,672	17,127,993	18,183,409
Workpeople employed	26,562	30,459	30,778
Total blast-furnaces	265	273	281
Active blast-furnaces	229	242	253
Length of campaign, weeks	10,846	11,661	11,587
Foundry pig iron, metric tons	944,356	1,089,108	1,232,126
Value per ton, shillings	51·37	53·78	54·95
Bessemer and basic pig iron, metric tons	4,054,761	4,481,700	4,850,368
Value per ton, shillings	45·69	49·38	50·32
Forge pig iron, metric tons	1,330,838	1,256,392	1,172,802
Value per ton, shillings	46·69	51·99	53·08
Direct castings, metric tons	32,591	42,923	45,440
Value per ton, shillings	102·70	104·04	93·22
Scrap, metric tons	10,029	11,343	12,031
Value per ton, shillings	41·64	43·62	40·19

In these tables the mark is taken as being equal to a shilling.

Foundries diminished in number from 1267 in 1896 to 1213 in 1898, but their pig and scrap re-melted increased from 1,570,155 tons in 1896 to 1,680,989 tons in 1897 and 1,824,165 tons in 1898; the workpeople employed being 74,536 in 1896, 79,844 in 1897, and 85,435 in 1898. The products amounted to 1,384,008 tons in 1896, 1,473,211 tons in 1897, and 1,597,434 tons in 1898, the average value per ton having been 166·36 shillings in 1896, 171·48 shillings in 1897, and 175·29 shillings in 1898.

Production of Weld Iron and Weld Steel.

	1896.	1897.	1898.
Active works	193	186	176
Workpeople employed	39,684	39,958	38,135
Semi-manufactures made, metric tons	86,700	79,893	82,911
Manufactures made, metric tons	1,113,559	1,031,691	1,077,363
Value of semi-manufactures per ton, shillings	83·09	92·46	89·04
Value of manufactures per ton, shillings	128·34	137·61	139·38

Production of Ingot Metal.

	1896.	1897.	1898.
Active works	154	164	170
Workpeople employed	83,302	91,526	106,459
Semi-manufactures made, metric tons	1,358,245	1,273,089	1,423,173
Manufactures made, metric tons	3,462,736	3,863,469	4,352,831
Value of semi-manufactures per ton, shillings	77·73	84·15	85·64
Value of manufactures per ton, shillings	125·70	131·02	134·92

The author also gives a series of other tables in which fuller details are given. The production of wire has diminished from 549,014 tons in 1896 to 476,067 tons in 1898, but on the other hand the production of rails and rail-fastenings increased in the same period from 582,534 tons to 819,100 tons. There has been, on the whole, a marked general increase of production of iron and steel manufactures in the years passed in review.

Another table deals with the production of coal and brown coal. This shows the production of coal to have been 85,690,233 tons in 1896, 91,054,982 tons in 1897, and 96,309,652 tons in 1898. The value per ton increased from 6·96 shillings in 1896 to 7·37 in 1897, and the number of workpeople from 316,513 to 357,695. In 1896 the production of brown coal was 26,780,873 tons; in 1897, 29,419,503 tons; and in 1898, 31,648,898 tons. The average value per ton was the same in 1898 as in 1896—2·32 shillings per ton, but the workpeople employed had increased during this period from 38,195 to 42,812.

The production of pig iron in Germany, including Luxemburg, was as follows in the year 1899: *—

	Metric Tons.
Forge pig iron and spiegeleisen	1,663,571
Bessemer pig iron	516,950
Basic pig iron	4,424,052
Foundry pig iron	1,424,732
Total	8,029,305

The total production in 1898 was 7,402,717 tons.

The proportion of the total borne by each kind of pig iron will be seen from the following table:—

	Per Cent. of Total.	
	1899.	1898.
Forge pig iron and spiegeleisen	20·7	21·1
Bessemer pig iron	6·4	7·2
Basic pig iron	55·1	54·1
Foundry pig iron	17·8	17·6

The production of pig iron in the different iron-smelting districts of the Empire was as follows:—

* *Stahl und Eisen*, vol. xx. p. 164.

	Production.	Per Cent. of Out-turn.			
		Forge and Spiegel.	Bessemer.	Basic.	Foundry.
	Metric Tons.				
Rhenish-Westphalia	3,186,704	19·8	76·8	42·0	42·1
Siegen, Lahn district, } and Hesse-Nassau }	678,054	29·6	3·9	0·4	10·3
Silesia and Pomerania	825,019	23·7	10·4	5·3	10·2
Saxony	25,391	1·0	0·0	0·0	0·7
Hanover and Brunswick	349,156	0·4	8·9	5·1	5·1
Bavaria, Würtemberg, } and Thüringen }	145,222	1·2	0·0	2·3	1·8
Saar district, Lorraine, } and Luxemburg }	2,819,759	24·3	0·0	44·9	29·8
Totals	8,029,305	100·0	100·0	100·0	100·0

The production of basic steel at German works in 1899 was as follows:—

	Metric Tons.
Basic Bessemer	3,973,225
Basic open-hearth	1,693,825
Total	5,667,050

Imports and Exports.—The following is a statement of the imports and exports of Germany during 1899:—

	Imports.	Exports.
	Metric Tons.	Metric Tons.
Pig iron	63,140	53,102
Old iron	612,651	182,090
Angle iron	898	221,164
Railway materials	4,737	180,898
Rods and bars	38,520	217,369
Plates, sheets, &c.	32,749	157,745
Wire and wire ropes and nails	8,852	209,309
Cast and wrought iron	29,768	68,390
Anchors, chains, &c.	2,664	727
Heavy parts of machinery	285	1,901
Parts of sewing-machines	1,541	5,164
Tubes for different purposes	35,723	205,509
Screws, bolts, &c.	6,478	2,289
Wheels and parts thereof	513	1,519
Arms, &c.	188	801
Other descriptions	1,103	1,739
Totals	839,810	1,509,716

The total for the imports in 1898 was 724,784 tons, and exports 1,626,046 tons, compared with 600,721 tons and 1,392,945 tons respectively in 1897.

The Returns of the Imperial Statistical Bureau show that the German imports and exports last year included :—

	Imports.	Exports.
	Metric Tons.	Metric Tons.
Iron ores	4,165,372	3,119,877
Manganese ores	196,825	7,040
Slags and slag wool	890,511	25,565

Mineral Statistics of Saxony.—There was produced in Saxony in 1898 :—

	Production.	As Compared with the Production in 1897.	
		Increase.	Decrease.
	Metric Tons.	Metric Tons.	Metric Tons.
Coal	4,436,455	...	135,230
Brown coal	1,180,928	107,689	...
Iron ore	5,671	...	7,510
Pig iron	24,422	...	...

The average quantity produced per workman employed amounted to 201·2 tons in the case of coal and 517·9 tons in the case of brown coal. There is only one blast-furnace in the country, and this was in blast all the year. It gave employment to 167 workpeople, and smelted 58,686 tons of ore and 15,737 tons of various additions. There were 31 collieries in operation, giving employment to 22,019 workpeople, and 90 brown coal mines, employing 2125 workpeople. The 32 existing ore mines gave employment to 4514 workpeople. Of the coal mined, 155,234 tons were converted into 72,245 tons of coke and 5321 tons of briquettes, and from 285,527 tons of brown coal briquettes to the weight of 71,576 tons were produced.*

Mineral Statistics of Alsace-Lorraine.—The mines and works of Alsace and Lorraine in 1898 produced :—

	Metric Tons.
Coal (Lorraine)	1,074,150
Iron ore	5,955,352
Pig iron	994,020
Castings	20,588
Wrought iron	69,456
Steel	304,665
Petroleum (Lower Alsace)	23,190
Asphalt	5,031

Accidents in Iron Smelting.—R. Krause * gives statistics dealing with the accidents that happened in Germany in 1897 in connection with iron smelting. The accidents were at the rate of 8·64 per thousand employed, as compared with a general rate for the Empire of 6·91. These figures relate to the statistics obtained in connection with payments made by the Imperial Insurance Bureau. The percentage of accidents in ironworks varied very considerably in different parts of the Empire. Thus in Saxe-Coburg-Gotha it was only 3·74, while it reached as much as 31·50 in Mecklenburg-Schwerin. In Prussia it was 8·95, in Bavaria 8·04, and in Alsace-Lorraine 8·23.

Coke.—The production of coke by the Westphalian Coke Syndicate in 1899 amounted to 7,045,924 tons, as compared with 6,415,685 tons in 1898. In nine years the output has increased 78 per cent. The largest producer was the Harpener Mining Company, which made 915,220 tons.

The Scarcity of Coal in Germany.—A correspondence is published † which passed between the *Verein zur Wahrung der gemeinsamen wirthschaftlichen Interessen in Rheinland und Westfalen* and the *Königliche Eisenbahn-Direction* regarding the coal famine in Germany in December 1899. It begins with a letter dated December 22, in which a complaint is made that while on the previous day 16,720 10-ton waggons had been asked for for coal transport, the railway authorities had only provided 12,159. This failure on the part of the Prussian railways to provide waggons had resulted in a coal famine throughout the whole of Rhineland and Westphalia, and various suggestions were made as to how this might have been prevented. The railway authorities attribute the unfortunate state of affairs to severity of weather, the rails being covered with a coating

* *Stahl und Eisen*, vol. xx. pp. 158-160.

† *Ibid.*, pp. 155-158.

of ice which was renewed immediately after every passing train, leading to complete disorganisation of the goods traffic, and it was added that works do not pay sufficient attention to the necessity of laying in adequate fuel supplies, a case being specially mentioned of a large ironworks in the district under consideration which employed 2500 workpeople, and which was obliged to close down in only two days after the commencement of the fuel difficulties on the railway.

In their reply to this letter the Association considers that the weather was only partly to blame, and was not the sole cause, as suggested by the railway authorities. The lubricants, for instance, that were used for the waggon axles froze much too readily, and this they think was quite as much the cause of the stoppage of trains as the ice incrustation on the rails; and it is further pointed out that the suggestion of the railway management, that works should lay in adequate supplies of fuel is quite impracticable in large works, which use over 100, or it may be even 200 to 280 waggon-loads of coal per day.

The consumption of coal, coke, and briquettes in Berlin in the first half of 1899 is stated to have amounted to 1,169,892 tons, 99,734 tons having been derived from the United Kingdom, as compared with 153,351 tons in the similar period of 1898. In addition to the above, 482,440 tons of brown coal and brown coal briquettes were also employed.*

Coal in Prussia.—The production of coal in Prussia in 1899 amounted to 94,778,252 tons, or 5·81 per cent. more than 1898. The number of miners employed was 342,324. The production of the different districts was as follows:—

	Tons.
Breslau	27,963,442
Halle	8,242
Clausthal	664,228
Dortmund	54,641,120
Bonn	11,501,220

The production of brown coal is estimated at 28,466,212 tons, or 9·21 per cent. more than in 1898. The largest production was in the Halle district, where the output was 23,392,402 tons.

It is pointed out by Schultz† that Prussia is the third largest coal-producing country in the world, only the United Kingdom and

* *Zeitschrift des oberschlesischen Berg- und Hütten-Vereines*, 1899, p. 307.

† *Stahl und Eisen*, vol. xx. pp. 223-220.

the United States exceeding it in the output of coal. In 1898 the United Kingdom occupied the premier position, the United States being next, and Prussia third with 89,573,528 tons, the workpeople employed in coal-mining in Prussia being 323,417 in number.

In all probability, the author observes, the age of steam is now at its end, that of electricity taking its place. In view of this, it becomes necessary to seek for sources for generating electricity which would be less costly than coal. One such undoubtedly lies in water power. Wind power is of less importance. In the atmosphere itself there is at times, and locally, an enormous storage of electricity at extreme tension. Thus tensions of 200,000 volts and more may occur, but whether it will be found possible to utilise these in practice it is as yet, of course, impossible to say. Even then, however, the use of coal for generating electricity will not be at an end. In this connection the author discusses the probable date of exhaustion of the German coalfields, adversely criticising the report of a recent German Commission on this subject, which thought that the coal resources of Westphalia, down to a depth of some 2400 feet, would be exhausted in 51 years. Below this depth the author calculates that there are still vast stores of coal remaining, which he thinks would last in all some 1293 years on the basis of an annual output of 100,000,000 tons.

The Brown Coal Industry of the Rhine District.—F. Heiman * draws attention to the rapid development of the brown coal deposits of the Rhine district. He points out that at many brown coal mines in this district central electric power generating plants are erected, which, being served by the brown coal at the colliery itself, can sell their power very cheaply—cheaper, indeed, than anywhere else in Germany. The Rhenish brown coal basin is surrounded with a perfect network of railways, and with these the brown coal collieries have made contracts, in virtue of which the transport charges per ton are to diminish with the increase in the output of the brown coal mines. The use of the brown coal for firing purposes is rapidly extending. It does not make clinker. The active brown coal mines in the Rhine district have increased 17 per cent. in number in a couple of years.

The Shipping Industry.—The following details are published with regard to the German mercantile marine.† The position it

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 544-546.

† *Stahl und Eisen*, vol. xx. p. 110.

occupies in the world's trade will be seen from the following table:—

Owned by	Percentage of Total World's Shipping in	
	1870-71.	1898-99.
United Kingdom	48·9	54·9
United States	16·1	5·7
Germany	5·6	8·2
France	6·3	4·8
Norway	4·1	4·8
Italy	4·4	2·6
Spain	3·1	2·6
Russia	1·8	2·3
Austria	1·8	1·4

This table shows that the United Kingdom has increased its already large proportion of the total shipping trade during the years in question until it now owns more than half the total shipping in the world. Germany, though very far behind, has also made progress, and now occupies the second place. Since 1890 the percentage of the total world's shipping owned by the United Kingdom has shown signs of decadence, having been then 58·7. The progress made by the German shipping industry becomes strikingly manifest when the ships owned by the larger shipping companies are taken into consideration. This will be readily seen from the following table:—

Name of Company.	Number of Ships Owned.	Net Register Tonnage of Ships.
Hamburg-American	85	261,135
North German Lloyd	78	224,010
British India Steam Navigation	102	181,213
Peninsular and Oriental	58	157,076
Nippon Yusen Kabushiki	84	130,000
T. Wilson, Sons, & Co.	86	116,902
Messageries Maritimes	64	115,172
Navigazione Generale Italiana	101	113,491

This rapid progress of the shipping industry of Germany has been largely due, it is pointed out, to the great improvements that have taken place in the harbour accommodation available. Ships drawing 19 feet 7 inches can now enter Bremen, and in a few years ships drawing 23 feet will be able to enter Stettin, and those drawing as much as

26 feet Lübeck. Königsberg will be another deep-water harbour. The position now held by the various German harbours is shown from the following table :—

	Tonnage Handled.
Hamburg (1897)	12,258,922
Bremen (1898)	3,624,388
Stettin (1898)	3,178,717
Lübeck (1898)	1,762,303
Danzig (1898)	1,442,231
Königsberg (1898)	1,171,117

It will be observed that the tonnage of the two North Sea ports is more than double that of the four East Sea ports. Hamburg is especially favoured in consequence of the Kaiser Wilhelm Canal.

Mineral Statistics of Luxemburg.—According to the report of the Luxemburg Chamber of Commerce, there were in 1887 in the Grand Duchy 68 mines in operation with an output of 5,349,009 tons of iron ore, 5662 persons being employed. There were 27 blast-furnaces, with a total production of 872,457 tons of pig iron, 2916 persons being employed. There were also 8 foundries producing 9874 tons of castings, and employing 286 persons, and one wrought iron and steel works at Düdelingen, producing 143,692 tons, and employing 1360 persons.

IX.—HOLLAND.

Coal-Mining.—Coal-mining in Holland is in a prosperous condition. In 1898 the Limburg Collieries produced 150,398 tons, or 253 tons more than in 1897. The number of persons employed was 489. The Kerkrade Collieries raised 106,418 tons, and employed 329 persons.

X.—INDIA.

Mineral Statistics.—The statistics of mineral production in India for the five years 1894 to 1898 have just been issued by the Department of Revenue and Agriculture. About a million tons of salt are produced annually from rock-salt, from salt lakes and wells,

and from sea-water. The coal industry is expanding rapidly, the output having increased from nearly three million tons in 1894 to over four and a half million tons in 1898. The coal is employed for railways, coasting and river steamers, and factories, but the conditions of transport are not yet sufficiently developed. Nearly twenty million gallons of petroleum were obtained in 1898 from Burma and Assam.*

XI.—ITALY.

Iron Trade Statistics.—The production of coal in Italy in 1898 was 341,327 tons,† while of iron ore the production was as follows:—

Province.	Number of Active Mines.	Number of Work- people.	Production in Metric Tons.
Leghorn (Elba)	5	1547	183,652
Bergamo	4	84	1,513
Brescia	8	227	3,436
Como	2	4	9
Novara	1	16	1,500
Totals	20	1878	190,110

The production of manganese ore was 3002 tons from seven active mines which employed 132 workpeople. The manganiferous iron ore raised was 11,150 tons from one mine employing 160 workpeople.

The production of iron and steel was as shown in the following table:—

	Number of Active Works.	Number of Work- people.	Production in Metric Tons.
Pig iron	8	247	12,387
Castings			12,675
Iron	195	13,181	167,499
Steel			87,467
Tin-plate			7,200

* See also *Engineer*, vol. lxxxix. p. 299.

† *Rivista del Servizio Minerario*, Rome, 1899; *Rassegna Mineraria*, vol. xi. pp. 227-228.

A general review is appended showing how the conversion of horse and steam power into electrically driven plants, in the greater use of water power, &c., are tending to affect the iron trade of Italy, which it is anticipated will make progress, although the production of pig iron from Italian iron ores is never likely to exceed certain narrow limits.

The imports of iron ore into Italy amounted to 5831 tons in 1897 and 8723 tons in 1898, while the exported quantities were respectively 207,619 and 217,556 tons. One point must not be overlooked, and that is, that should in the future the reduction of iron on a large scale by means of electricity become of importance, there will be an increased production of iron in Italy. Two new blast-furnace plants are probable, one for the Schneider Company, Creusot, on the coast of the mainland opposite Elba, and another for the Societa Anouima delle Ferriere Italiane at San Giovanni in the Val d'Arno, on the Island of Elba itself. The fuel required will be obtained partly from the United Kingdom and partly from Germany. Of late, two experimental importations have been made of coal and coke from the United States. German coke can be sold cheaper than coke from the United Kingdom in the North of Italy, and even in Milan, but at Genoa the opposite is the case, and in this latter neighbourhood there is a rising iron industry. Details are given in tabular form as to the quantities of the various kinds of iron and steel imported into Italy in the years 1894-98, and as to their sources of origin. The importation of pig iron increased from 119,267 tons in 1884 to 169,059 tons in 1898, over 20,000 tons of which came from the United States, and this quantity is still increasing rapidly, for in the first five months of 1899 the quantity imported from the United States was as much as 23,882 tons. The quantity obtained from Spain shows no increase.

XII.—JAPAN.

Steel-Making.—The progress that has of late been made by Japan in connection with the manufacture of iron and steel is considered by E. Schrödter.* After briefly referring to the great changes that have taken place in Japan in the last twenty years, the author

* *Stahl und Eisen*, vol. xix. pp. 1141-1151; 12 illustrations.

gives details showing the foreign trade of Japan in 1898. This was as follows :—

To and From	£
United Kingdom and Colonies	17,424,600
United States	8,913,150
China	6,046,150
Germany	2,866,500
France	2,804,900

Details are given as to the value of each of the more important imports, and more particularly of the iron and iron wares imported. These included :—

	1898.	1897.
	Tons.	Tons.
Pig iron	62,898	43,295
Bar iron	71,807	54,809
Galvanised sheets	3,641	4,150
Nails	14,263	18,035
Plates	22,996	19,395
Rails	71,520	86,401
Wire	6,079	7,673
Steel	5,793	3,813

The following was the value of the imports :—

	1898.	1897.
	£	£
Iron wares	467,331	144,172
Railway material	63,870	208,457
Pipes	136,070	93,185
Tin-plates	42,000	58,328

The position occupied by the United Kingdom and dependencies is again a very prominent one. The author points out that the most remarkable point about the export trade of Japan lies in the steady increase in the manufactured articles. According to the statistics collected by a former Japanese Minister for Trade and Agriculture, Nagabonmi-Ariga, the value of the manufactures has reached the following percentage of that of the total exports :—

	Percentage of Total.
1889	64
1893	71
1895	77
1897	78
1898	80

Similarly there has been a steady increase in the relative value of the raw materials imported as compared with that of the manufactures imported.

The main centres of industry are Osaka, Kioto, and Tokio, in the order in which these names are given. At present in Japan there are 2968 factories in which use is made of steam-power, the 5375 steam-engines having 58,172 horse-power. These works give employment to 273,792 workpeople, while all other factories only employ 140,243 workpeople. The factories using steam power have consumed the following amounts of coal :—

	Tons.
1895	750,000
1896	1,092,000
1897	1,888,000
1898	1,553,000

The quantity of iron made in Japan is shown below for the years mentioned. It was mostly foundry pig iron :—

	State Works. Tons.	Private Works. Tons.
1886 . . . . .	...	9,836
1890	2,196	18,875
1893	1,188	15,867
1894	1,211	18,274

Since then the State has erected modern steelworks, details of which are given.

Chinese pig iron is now imported into Japan. Some time ago a sample lot of 1000 tons was imported from the Hauiyang Ironworks, and found quite good enough for ordinary purposes. A second order for 2000 tons consequently followed, and this has led to a regular business with the Hauiyang works. The total annual consumption of pig iron by Japan is estimated at 48,000 tons.

XIII.—NATAL.

Coal Production.—The output of coal* during 1898 amounted to 387,811 tons. In 1899 there are no returns for November and December on account of the war. The aggregate output for the first ten months of 1899 (estimating the production in October at 16,000 tons) amounted to 324,161 tons.

* *Reports on the Mining Industry of Natal.* Pietermaritzburg, 1899.

XIV.—*PERSIA*.

Mineral Resources.—H. Winklehner* observes that early in the nineties an English company was granted the sole right of mining in Persia, except for the precious metals and precious stones, and that he was appointed by this company to prospect for minerals those provinces of Persia which border on the Persian Gulf. He now describes the results of his investigation. He proceeded in the first instance to Bushir, on the Persian Gulf, and observes that the climate is so hot and enervating that ordinary European labour would be incapable of utilisation, and that native labour would have to be employed in any mining undertakings in this region. Such labour is altogether unskilled. Other difficulties lie in the absence of roads, in the great distances inhabited places are apart, and in the general absence of water. This latter in particular renders prospecting a matter of much difficulty. During two and a half years the author prospected throughout the provinces of Ghermsir, Farsistan, Charistan, Kerman, Yesd, Beludshishan, &c., as well as islands in the Persian Gulf, the whole district being of about the size of Hungary. He deals generally with the various mineral deposits, and some of these are referred to under their respective headings in these abstracts. Minerals other than those so dealt with are, however, also mentioned.

Southern Persia consists mainly of limestone. The limestone ranges reach heights exceeding 13,000 feet. There are very few fossil remains, but the geological age is undoubtedly mainly cretaceous. Basalt and trachyte burst through the chalk in places, and formations more recent than cretaceous are also occasionally met with. The author is of opinion that under existing conditions a mining undertaking in Persia would be hopeless. Eighty per cent. of the country is sandy desert or bare mountains; it is very thinly populated, and there is not a single decent road in the whole of Persia except one between Teheran and Kaswin, which is in very bad repair, and another from Teheran to Kum and Kashan. Were coal and petroleum to exist in the neighbourhood of the Persian Gulf, they would be of importance, but there are no deposits of the former, and those of the latter are not likely to be developed yet awhile. Wood and water are so scarce, that metal mining would have great difficulties to contend

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 629-633 and 645-649.

against. Adequate transport facilities must first exist before there is any hope, the author thinks, of possible progress for the mining industry of Persia.

XV.—RUSSIA.

Mineral Statistics.—According to the *Bulletin Russe de Statistique*, the mineral production of Russia in 1897 included :—

	Tons.
Iron ore	3,930,159
Chrome iron ore	10,812
Manganese ore	366,513
Coal	11,119,849

The metallurgical production comprised :—

	Tons.
Pig iron	1,838,712
Wrought iron	507,141
Steel ingots	503,614
Rails	366,809

Preliminary returns show that the mineral production in 1898 included 567,594,000 poods of coal.*

The rapid progress made in recent years by the coal, oil, and iron industries of Russia is seen from the following table, giving the production in the years mentioned in millions of poods : †—

	1877.	1881.	1892.	1897.	1898.
Coal	110	277	424	684	746
Petroleum	13	167	399	478	507
Pig iron	23	36	64	113	134
Iron	16	22	29	30	30
Steel	3	14	31	74	90

Iron Trade Statistics.—The production of pig iron in Russia in 1898 amounted to 135,635,513 poods, as compared with 113,982,000 poods in the previous year. The production of malleable iron remained about the same, but the production of steel rose from 52,964,000 poods

* *Gorny Zavodski Listok*, 1900, No. 6.

† Communicated by Mr. Sergius Kern.

in 1897 to 69,926,325 poods in 1898. The production was as follows in the different parts of the Empire : *—

	Pig Iron.	Malleable Iron.	Steel.
	Poods.	Poods.	Poods.
13 Northern works	1,611,666	3,663,674	7,903,653
106 Ural works	43,539,106	15,432,995	7,997,709
46 Central Russian works	11,016,032	3,910,194	6,951,917
15 Southern works	61,188,495	2,589,627	35,574,152
5 South-Western works	186,238	105,790	...
36 Polish works	16,069,931	3,934,157	11,460,201
3 Siberian works	538,840	121,310	297
State works	91,825	58,206	1,006
Finnish works	1,393,380	641,460	39,390
Totals	135,635,513	30,457,413	69,928,325

The imports of pig iron into Russia in 1898 amounted to 6,094,000 poods, of unmanufactured iron and steel to 22,870,000 poods, and of manufactured steel and iron, including machinery, to 11,325,000 poods. Calculated as pig iron, this corresponds to about 57,386,000 poods of pig iron in all, or an increase of 5,139,000 poods as compared with the imports in 1897. The total consumption of pig iron in Russia in 1898 was thus 193,021,000 poods, or about 1·53 pood per individual (one pood equals 36·1 lbs.), taking the population as 126,000,000. The production of pig iron is steadily and rapidly increasing in Russia, while the consumption per head of the population has been as follows :—

	Poods per Head.
1893	0·80
1894	1·06
1895	1·13
1896	1·15
1897	1·31
1898	1·53

The consumption has increased at a more rapid rate than the production.

Preliminary official statistics give † the Russian production in 1898 as follows :—Pig iron, 125,524,000 poods ; wrought iron, 32,947,000 poods ; steel, 67,695,000 poods. The Government works produced : Pig iron, 5,419,000 poods ; wrought iron, 1,919,000 poods ; steel, 769,000 poods.

Statistics collected by the Russian Ironmasters' Association ‡ show the

* *Riga Industrie Zeitung ; Stahl und Eisen*, vol. xx. p. 172.

† *Gorny Zavodski Listok*, 1900, No. 6.

‡ Communicated by Mr. Sergius Kern.

production of pig iron in Russia during the first half of 1899 to have amounted to 1,337,000 tons. This is at the rate of 2,674,000 tons per year, in which case the production of pig iron in Russia in 1899 would exceed the production in 1898 by as much as 450,000 tons. How rapid the increase in the production has been is evident from the fact that in 1897 it was only 1,863,696 tons and in 1898 2,223,534 tons. The following table shows the way in which this increase in the production has been distributed over the iron-producing sections of the Empire :—

District.	Production of Pig Iron.		
	1897.	1898.	1899 (est.).
	Metric Tons.	Metric Tons.	Metric Tons.
The 13 ironworks of the North	4,888	26,421	32,230
The 105 ironworks of the Ural	669,120	713,756	785,949
The 45 ironworks of the Trans-Moscow } district	169,696	180,591	262,953
The 17 Southern ironworks	755,446	1,003,090	1,262,063
The 5 South-Western ironworks	2,752	3,053	2,995
The 41 Polish	228,546	263,441	296,502
The 3 Siberian	8,109	8,834	4,894
The Finnish and State works	25,139	24,348	26,200
Totals	1,863,696	2,223,534	

The ratio of production in the three years above reviewed has been 100, 119·3, 143·5. It is probable that this increase in production will continue, and even more rapidly, in view of the new discoveries of iron ore in Central and other parts of Russia. The importance of the recent ore discoveries in Central Russia is evidenced by the increase in the production of the blast-furnaces in the Trans-Moscow district. Up to the period of increase the blast-furnace district had shown no signs of any greatly increased production. According to preliminary reports received, it may be assumed that the total production of pig iron in Russia for the year 1899 must reach 163,100,000 poods, against 135,600,000 poods in 1898.

The official report of the Mining Department of South Russia for the year 1898 contains the following statistics : *—

In 1898 seventeen metallurgical works were in operation. They employed 524 steam-engines, total horse-power, 89,900 ; 3 oil-engines, total horse-power, 22 ; 65 portable engines, total horse-power, 3090 ; 51 steam-

* Communicated by Mr. Sergius Kern.

hammers, 47 rolling-mills, 27,025 workmen, and 12,054 auxiliary workmen. The works used : wood, 2,155,420 cubic sagesnes ; coke, 69,649,571 poods ; coking coal, 89,833,088 poods ; anthracite, 137,028 poods. There was raised at the mines : iron ores, 126,954,390 poods. The number of workmen employed was 6499. There were produced at the seventeen works : pig iron, 57,784,254 poods ; wrought iron, 2,055,603 poods ; steel, 41,260,599 poods ; cast iron, 3,460,270 poods ; iron wire, 390,684 poods. The manganese ores mined amounted to 3,640,475 poods, and the number of workmen employed to 964. The number of workmen injured at the works was 469, and at the mines, 474. The explosives used in mining work consisted of dynamite, 8360 poods, and powder, 26,511 poods.

An interesting table is given by N. von Dittmar.* In 1898 the Southern Works manufactured 57,487,151 poods of iron and steel, which were used thus :—

For Government purposes .	19,322,947 poods (33·5 per cent.).
For the market	34,218,733 „ (60 „).
For the use of the works .	3,945,770 „ (6·5 „).

These articles include pig iron, wrought iron, steel of different qualities, cast iron, and steel castings, rails, and bridge-work.

In the South of Russia :—

In 1897, 24 blast-furnaces produced	46,142,194 poods of pig iron.
In 1898, 29 „ „ „	60,912,280 „ „

From this it follows that every furnace, as an average, produced :—

In 1897	1,922,260 poods of pig iron.
In 1898	2,100,000 „ „

That is, that the average production per furnace is increasing, owing to the construction of larger furnaces, having an increased output.

The Iron Industry of the Ural.—The production of iron in the Ural is stated by M. Verstraete† to have been as follows in the years mentioned, the quantities being given in poods :—

Year.	Total Production in the Ural	Total Production in all Russia.
1893	17,035,641	30,461,700
1894	17,630,554	30,572,000
1895	14,029,504	26,885,635
1897	15,527,450	29,680,000

* Communicated by Mr. Sergius Kern.

† *L'Oural*, 1899, p. 79.

It will be seen that the production of iron tends to diminish. The out-turn of steel, on the other hand, shows an increase. Most of the Ural iron is obtained by puddling. Scarcely 10 per cent. is made in charcoal-fired hearths. The puddling furnaces will in their turn give way to the open-hearth.

In another table * is given the production of steel in the Ural. This is also given in poods, and is as follows (roughly speaking 62 poods are equivalent to a ton) :—

Year.	Total Production in the Ural.	Total Production in all Russia.
1893	3,927,232	38,509,418
1894	4,639,036	44,322,395
1895	8,330,945	53,666,077
1897	6,523,280	53,000,000

Most of the steel obtained in the Ural is made in open-hearths, the Bessemer process being only slightly employed. Rails are made at three works only, two of these using Bessemer plants.

The production of pig iron is stated elsewhere † to have been as follows, in poods :—

Year.	Pig Iron.	
	Total Production in the Ural.	Total Production in all Russia.
1889 . . .	24,700,000	45,180,305
1891 . . .	29,900,000	60,653,073
1893 . . .	31,000,000	69,547,777
1895 . . .	33,300,000	88,190,523
1897 . . .	40,880,000	113,037,253
1898 . . .	42,678,852	132,578,852

The production of pig iron in the Ural has progressed at a considerably slower rate than in most other parts of Russia. This is, of course, accounted for by the fact that the fuel employed is charcoal. While at certain works in the Donetz basin there are blast-furnaces which make about 170 tons of pig iron daily, the largest blast-furnaces in the Ural only make one-fifth of this quantity. In 1895, of the 117 existing blast-furnaces, 87 had cold blast only. The cost at the furnaces of the

* *L'Oural*, 1899, p. 83.

† *Ibid.*, pp. 66-73.

ore required to produce one pood of pig iron is given in tabular form for seven different groups of Ural blast-furnaces, and is shown to vary from between 4 and 5 kopecks in the Tcherdine (Koutim) district, and over 23 kopecks in the Northern Ural district, say from 6½d. to 2s. 6d.

With regard to the quantity of fuel required to produce the ton of pig iron, this varies from about 0·8 to 0·9 ton in the case of ore from the Bakal mines, which is very readily reducible, to about a ton and a half in the case of the sphaeroidites of the province of Viatka. The cost of the fuel required to produce in the blast-furnaces one pood of pig iron is stated to vary from about 12 to 18 kopecks (say 1s. 4d. to 2s.). It is not possible to avoid the transport of fuel in the case of the Ural blast-furnaces, but care is taken to put these in the vicinity of the ore deposits to reduce to a minimum the cost of transport of the ore.

In a further table a general epitome is given of the first cost of the ton of pig iron at the seven groups of blast-furnaces previously mentioned. These represent the whole of the Ural districts. The total cost of the ton of pig iron varies from about £2, 2s. 6d. in the case of the works using the Bakal ores, to about £3, 14s. 6d. in the case of those using the ores of the provinces of Viatka and Vologda, the works in each case being in the immediate vicinity of the iron ore deposits.

Full details are given as to the outputs of the different Ural works.* Private and State works are separately referred to. The former produced in 1898 nearly eight times as much pig iron as the works belonging to the State, nearly eleven times as much malleable iron, and twenty-two times as much steel, the statistics for malleable iron and steel relating to 1897.

The *Echo des Mines* also discusses the development of the mining and metallurgical industries of the Ural. Last year the blast-furnaces furnished 722,000 tons of pig iron, as compared with 454,000 tons in 1890. Since 1886 the out-turn has doubled, and during the current year further progress will be made owing to the starting of seven new blast-furnaces with a capacity of 65,000 tons. The collieries on the western side of the Ural have not increased their output, which for the past three or four years has been about 360,000 tons. The coal is of inferior quality, and will not bear the cost of long transport. The absence of a light railway renders the output of anthracite on the eastern side insignificant.

In 1900 four new ironworks will commence operations in the Ural, with seven or eight blast-furnaces, to be erected at existing ironworks.

* *L'Oural*, 1899, pp. 178-181.

These new furnaces will give not less than 5,000,000 poods of pig iron, so that the yearly production of the Ural ironworks in 1900 will be nearly 50,000,000 poods of pig iron.

In South Ural, in the Tcheliabinsk district, there exist excellent manganese ores, containing on the average 52 to 56 per cent. of manganese. In Moscow a company is formed to start a blast-furnace in that district for the production of ferro-manganese, with a capital of 250,000 roubles.*

A New Russian Steelworks.—The Providence Russe Ironworks at Mariapol possesses ore concessions in the Crimea and in the Krivoi Rog, and bog iron ore deposits near Mariapol and Elénovka. The phosphoric and manganiferous iron ore deposits of the Crimea have been opened up on a considerable scale. At present 16,000 tons of ore a month are being wound, but this quantity will, it is anticipated, soon be raised to from 30,000 to 40,000 tons per month. The bed of ore mined at Krivoi Rog is about 26 feet in thickness. The ore contains some 60 per cent. of iron. The bog iron ores found near the blast-furnaces contain 45 per cent. of iron. Two blast-furnaces are erected, a third is in course of erection, and a fourth arranged for. In the working year 1898–99 the works possessed 126 Coppée coke-ovens.

In addition to the blast-furnace plant, the works is provided with an open-hearth steel plant with two furnaces, which yield 3000 tons of ingots per month. These are used for conversion into sheets. There are also in course of erection at this works a bar iron and beam plant, and a basic Bessemer plant with three 15-ton furnaces. The works has also provided for harbour accommodation near Mariapol with railway connection, and possesses large coal reserves in the centre of the Donetz basin.†

Detailed particulars have been published ‡ of the works of the Ural Volga Metallurgical Company. At the Tsaritsyne Works the first open-hearth furnace was started a year ago. At the present time there are six of these furnaces, with an aggregate capacity of 65,000 to 75,000 tons of ingots. The first plate-rolling mill was started in January 1899. Its present production is 1600 tons a month. The merchant mill began rolling in April 1899. Various other mills are in full work, and the production at the beginning of next year will be 5000 tons a month. The fuel employed throughout the works is petroleum residues. All the

* Communicated by Mr. Sergius Kern.

† *Stahl und Eisen*, vol. xx. p. 183.

‡ *Moniteur des Tirages Financiers*, November 25, 1899.

motors are compounded, and there is a central condensing plant. Electric power is largely used for transport. The pig iron required is brought along the Volga from blast-furnaces belonging to the company at Avzian and Lemeza, where there is an abundant supply of iron ore.

The Coal Industry.—The production of coal in the Ural has been as follows in the years mentioned : *—

	Poods.
1890	15,200,000
1891	14,900,000
1892	15,400,000
1893	15,900,000
1894	17,000,000
1895	15,700,000
1896	20,000,000
1897	22,600,000
1898	20,100,000
1899	22,000,000

It will be seen that the progress made has been remarkably slow. This is probably due to the fact that the coal found on the western slopes is of poor quality, while that on the eastern slopes is handicapped by the absence of transport facilities.

The coal crisis in Russia and the main sources of native supply are discussed by H. Cooke,† who quotes the following table to show the increased production of the country :—

	Millions of Poods.		
	1877.	1887.	1898.
Coal	110	277	746
Naphtha	13	167	507
Pig iron	23	36	134
Iron	16	22	30
Steel	3	14	90

During the same time the coal imports have risen from 95 to 196 million poods. The various coal-producing districts are briefly described, and reference is made to the present relaxation of duties and the Government control of price.

XVI.—SPAIN.

Mineral Statistics.—The mineral production ‡ of Spain in 1899 included 2,672,194 tons of coal, 70,195 tons of lignite, 351,901 tons of coke, and 382,666 tons of patent fuel. Of iron ore the production was

* *St. Petersburger Zeitung ; Stahl und Eisen*, vol. xx. p. 291.

† Foreign Office Report.

‡ *Revista Minera*, vol. li. pp. 69–73.

9,234,302 tons, or 2,037,255 tons more than in 1898. The bulk of the output was obtained in the province of Biscay, which heads the list of provinces with 6,146,542 tons. Santander follows with 1,285,440 tons; then Murcia with 670,198 tons, Almeria with 538,637 tons, and Seville with 319,360 tons. The three most productive iron-mining companies raised the following amounts:—

Ores.	Orconera.	Martinez-Rivas.	Franco-Belge.
Rubio	939,305	775,583	435,512
Campanil	14,837	...	82,616
Calcined carbonate	64,733	28,659	97,078
Totals	1,018,875	804,642	615,206

The exports of iron ore amounted to 8,613,137 tons, or 2,055,075 tons more than in 1898. Of the total exports, 6,224,229 tons went to Great Britain. The amount of iron ore consumed in Spain was 621,165 tons, the total production of the twelve ironworks in the kingdom being 295,840 tons of pig iron. There was also produced 68,300 tons of Bessemer steel ingots, 54,654 tons of open-hearth steel ingots, 66,568 tons of puddled iron, and 173,566 tons of forged iron and steel.

The coal statistics were as follows: *—

	1899. Tons.
Coal output	2,672,194
Lignite output	70,195
Coal imports	1,584,999
Coke imports	290,217
Total	4,617,605
Exports	8,084
Consumption	4,609,521
Patent fuel	382,666

Iron Ore Resources.—The quantity of iron ore remaining in Spain at the end of last year capable of being won is estimated at 1,305,000,000 tons.† Of this quantity 57 millions are attributed to Biscaya, 22 to Almeria, 10 to Santander, 34 to the Asturias, and 41 to the province of Lugo. It is in the provinces of Leon and Palencia, however, that the largest iron ore resources of Spain are to be found. These two provinces are estimated to possess reserves to the extent of as much as 760 millions of tons. Of this some 650 million tons is oolitic ore of low percentage.

* *Revista Minera*, vol. li. p. 69.

† *Revue Generale des Sciences; Echo des Mines et de la Metallurgie*, p. 6396.

How large this quantity is will be seen from the fact that it represents as much as eleven times the quantity of ore already mined in the Bilbao district, or fourteen times the quantity of ore reserves still remaining there. The ore is, however, phosphoric, like most of the ore contained in the Spanish ore reserves. It has been estimated that Spain possesses about 875 million tons of phosphoric ore, 150 million tons of hæmatite ore low in phosphorus, and 5 million tons of manganiferous ore. The following table shows the estimated iron ore reserves at the present time and the probable reserves in 1920 :—

	Present Time.	In 1920.
	Tons.	Tons.
Biscaya	57,770,000	...
Santander	10,000,000	...
Navarre }	3,500,000	...
Guipuscoa }		
Burgos }	10,000,000	6,650,000
Logrono }		
Soria	5,000,000	...
Murcia	22,600,000	9,850,000
Almeria	10,000,000	5,050,000
Grenada }	11,300,000	850,000
Cordova }		
Seville	2,300,000	320,000
Malaga	15,000,000	10,450,000
Huelva	3,200,000	150,000
Badajoz		
<i>Phosphoric ores.</i>		
Catalonia }	32,000,000	25,900,000
Aragon }		
Ciudad Real	8,000,000	6,450,000
Leon }	700,000,000	736,840,000
Palencia }		
Asturias	34,000,000	27,030,000
Lugo	41,000,000	28,940,000

Another estimate of the ore reserves of the province of Biscaya in 1920 places it at 980,000 tons, 600,000 tons belonging to the Orconera and 380,000 to the Franco-Belge companies.

During 1899 the number of vessels leaving Bilbao for foreign ports was 2924. The exports of iron ore amounted to 5,441,732 tons, and that of pig iron to 52,050 tons.*

Manganese Ore.—The amount of manganese ore exported from the province of Huelva during the year 1899 was 138,419 tons, of which 1335 tons went to Germany, 4842 tons to England, 4499 tons to France, and 127,743 tons to Belgium and Luxemburg.†

* *Revista Minera*, vol. li. p. 35.

† *Mining Journal*, vol. lxx. p. 41.

XVII.—*SWEDEN*.

Iron Trade Statistics.—The production in Sweden in 1899* was:—Pig iron, 497,727 metric tons; blooms and billets, 195,331 tons; Bessemer steel ingots, 91,898 tons; open-hearth steel ingots, 197,357 tons; iron ore, 2,435,200 tons; coal, 239,344 tons.

In Sweden the price of iron and steel continues to rise. The principal cause is the increased cost of charcoal. This fuel, which is so important to the Swedish iron trade, is becoming scarcer, owing to the fact that the numerous cellulose works started during the last ten years consume very large quantities of wood and pay higher prices than the charcoal-burners. Another cause for the rise in prices is the increased cost of labour. Much labour is absorbed by the railways in course of construction, so that in many iron and steel works there is an actual labour famine.

The Swedish exports last year included 1,627,908 tons of iron ore, 93,775 tons of pig iron, and 167,684 tons of bar iron.

On October 19, 1899, the *Times* published a leading article on Scandinavian politics, in which it was asserted that Sweden had no manufactures and commerce, and that, while it had stood still for eighty-five years, Norway had become a considerable manufacturing and commercial nation. A letter was subsequently published from Bennett H. Brough, pointing out the inaccuracy of these statements, and referring to the great development of the Swedish iron-mining and metallurgical industries, as seen by the members of the Iron and Steel Institute during their recent meeting in that country. The statements in the *Times* called forth indignant articles in the Swedish press, and the *Teknisk Tidskrift* published in its issue of December 2 a translation of the letter referred to, and gave particulars of the development of the Swedish manufacturing industries.

Iron Ore.—G. A. Granström † gives some interesting statistics of the Swedish production of iron ore. In 1887 in Sweden 902,200 tons of iron ore were raised by 6337 men, whilst last year 2,302,400 tons were raised by 9274 men. Of the total force of miners employed last year, 3055 were engaged in mining phosphoric iron ore, and 6219 in mining other ore. In 1892, of the 7564 miners engaged, only 749 were engaged in the extraction of phosphoric ores. Another interesting comparison shows that in 1892 of the material raised 51·7 per cent. consisted of ore, whilst last year 1,593,200 tons of ore and rock yielded 877,200 tons, or 55 per cent.

* Kindly communicated by Mr. R. Åkerman, Director-General of the Swedish Board of Trade, July 14, 1900.

† *Teknisk Tidskrift*, 1899, pp. 67-72.

XVIII.—UNITED STATES.

Iron Trade Statistics.—The American Iron Trade Association * reports the production of iron and steel in the United States in 1899 to have been as follows :—

	Tons.
Pig iron	13,620,703
Bessemer steel ingots	7,586,354
Bessemer steel rails	2,270,585
Basic open-hearth steel ingots	2,080,426
Acid open-hearth steel	866,890
Total open-hearth steel	2,947,316
All kinds of steel	10,639,857
All rolled iron and steel, including rails	10,357,397

Iron Trade Exports.—The iron and steel exports of the United States for the year 1899 have been published.† They show a total of 778,901 tons, against 841,905 tons for the previous year. The exports of steel rails show a decrease of over 122,000 tons compared with the corresponding period of 1898. The other prominent features of the record are a decrease of 21,000 tons in pig iron, and increases of 23,571 tons in sheets and plates and of 20,206 tons in structural iron and steel. Of wire nails and spikes, the total exports for the year have increased from 13,714 to 33,535 tons. The details are as follows :—

	1899.
Iron ore	40,690
Pig iron	228,640
Scrap	76,632
Bar iron	10,603
Bars or rods of steel other than wire	30,728
Steel rails	6,442
Billets and blooms	171,272
Hoop, band, and scroll	25,605
Rods, wire, of steel	2,869
Iron sheets and plates	16,992
Steel sheets and plates	6,196
Tin-plates, terne-plates, and taggers-tin	50,636
Structural iron and steel	133
Wire	54,244
Cut nails and spikes	11,634
Wire nails and spikes	9,974
All other nails, including tacks	33,535
	2,076
Total	778,901

Iron Ore in the Lake Superior District.—The total production of iron ore of the five ranges of the Lake Superior district since the commencement, forty-four years ago, amounts to 152,359,591 tons, of which over one-third have been produced in the last four years.‡

* *Annual Statistical Report of the American Iron and Steel Association*, 1900, p. 23.

† *Iron and Coal Trades Review*, vol. lx. p. 366.

‡ *Iron Trade Review*, February 1, 1900, p. 7, and Supplement.

Detailed statistics are given for all mines and years, and of these the following show the totals for the last three years :—

Range.	1897.	1898.	1899.
	Tons.	Tons.	Tons.
Marquette . . .	2,715,035	3,125,039	3,757,010
Menominee . . .	1,937,013	2,522,265	3,301,052
Gogebic . . .	2,258,236	2,498,461	2,795,856
Vermillion . . .	1,278,481	1,265,142	1,771,502
Mesabi . . .	4,280,873	4,613,766	6,626,384
Totals . . .	12,469,638	14,024,673	18,251,804

Coal.—A careful review of the coal resources of the United States has been published.* Owing to the exceptional ease and cheapness with which the coal can be mined, as well as to its accessibility to home markets, and to the readiness with which the best American coal can be brought to the seaboard, there is no doubt that in the near future America will be our most active competitor in the coal trade of the world. It will not be long before American coal will be found supplying all the Atlantic coaling stations, and possibly supplanting us down the coast of South America. Already, as a consequence of the war in South Africa, a great demand is reported for tonnage from the American coal ports to the Canaries, Marseilles, Barcelona, the River Plate, Rio Janeiro, the West Indies, and even to the Straits and China.

F. L. Hoffman † gives the statistics for several years of the fatal accidents in Canada and the United States. The average mortality is given as 2 per 1000 in soft coal-mines, and 2·9 to 3·0 per 1000 in anthracite mines.

The Iron Trade.—C. Kirchhoff ‡ discusses some of the new phases in the iron trade, such as the tendency towards consolidation of the various interests or the acquirement of control in the ore and coke supplies.

An elaborate series of articles has been published in the *Times* § on American engineering competition, in which special reference is made to the iron trade. Some of the conclusions are contested by Sir Lowthian Bell. ||

* *The Statist*, vol. xlv. pp. 1044–1045.

† *Engineering and Mining Journal*, vol. lxi. pp. 110–111.

‡ Address to the Manufacturers' Club of Philadelphia; *Iron Age*, November 16, 1899, pp. 8–9.

§ April 19, 20, 21, 24, 25, 26, 30, May 10, June 1, 4, 5, and 6, 1900.

|| *The Times*, June 12, 1900.

W. Garrett * discusses competition in American iron and steel.

The growth of the iron industry in the United States is discussed by F. W. Taussig.† Amongst the matters dealt with are the influence of the ore deposits of the Lake Superior region, the central position of • Pittsburg, and the labour question.

XIX.—COMPARATIVE TABLES.

The World's Production of Coal and Iron.—For purposes of comparison, the following summary of the production of coal in the principal countries of the world is appended :—

Country.	Year.	Production in Tons.
United Kingdom	1899	220,085,368
Australasia—		
New South Wales	1898	4,706,251
New Zealand	1898	907,033
Queensland	1898	407,934
Tasmania	1898	44,141
Victoria	1899	262,380
Austria, coal	1898	10,947,522
" lignite	1898	21,083,361
Hungary, coal	1898	1,239,498
" lignite	1898	4,206,694
Belgium	1899	21,917,740
Borneo	1898	41,587
Bosnia	1899	303,425
Canada	1899	4,565,993
Cape Colony	1899	171,301
France	1899	32,933,788
Germany, coal	1898	96,279,992
" lignite	1898	31,648,498
Greece	1898	171,310
Holland	1898	150,398
India	1898	4,568,880
Italy, lignite	1898	341,327
Japan	1897	5,647,751
Mexico	1898	126,251
Natal	1899	324,161
Peru	1898	10,000
Portugal, anthracite	1898	10,250
" lignite	1898	12,291
Roumania, lignite	1898	67,000
Russia	1898	10,250,000
Servia	1896	11,726
South African Republic	1898	1,953,026
Spain	1899	2,672,194
Sweden	1899	239,344
United States	1899	230,838,973

* Paper read before the Illinois Manufacturers' Association, December 13, 1899; *Iron Trade Review*, February 15, 1900, pp. 12-13

† *The Quarterly Journal of Economics*, February 1900.

A similar summary showing the production of pig iron is as follows :—

Country.	Year.	Production in Tons.
United Kingdom	1899	9,393,018
Austria	1898	957,837
Hungary	1898	439,404
Bosnia	1899	13,749
Belgium	1899	1,036,185
Canada	1899	94,077
France	1899	2,567,388
Germany and Luxemburg	1899	8,029,305
Italy	1898	12,387
Japan	1896	16,000
Russia	1898	2,193,750
Spain	1899	295,840
Sweden	1899	497,727
United States	1899	13,620,703

Iron Consumption.—According to the calculations of the Society of German Ironmasters, the production of pig iron per head of population in 1898 was as follows :—

	Lbs.
Germany	296
Great Britain	476
France	142
Austria-Hungary	64
Belgium	330
Sweden	248
Italy	1
Russia	38
United States	350

Imports and Exports.—Official statistics show that the imports (in tons) of the leading European iron-producing countries in 1899 were—

Country.	Iron Ore.	Pig Iron.	Iron and Steel.
Great Britain	5,486,395	199,754	391,671
Germany	3,516,577	409,442	112,079
Austria-Hungary	178,235	173,957	54,887
France	2,032,240	102,383	37,343
Belgium	2,252,530	394,767	66,226

The exports during the same year were as follows :—

Country.	Iron Ore.	Pig Iron.	Iron and Steel.
Great Britain . . . . .	...	1,413,146	1,835,222
Germany	2,933,734	307,434	1,312,364
Austria-Hungary	302,317	15,798	45,984
France	236,169	255,889	93,271
Belgium	381,827	39,924	664,595

J. S. Jeans * compares the exports of various classes of iron and steel in the raw and manufactured states from the leading countries in the last two years.

Petroleum.—In a general review of the petroleum industry of the world in 1899,† statistics, naturally more or less incomplete, are given for the various producing countries.

The development of the petroleum industry is one of the most remarkable features of the latter half of the nineteenth century. In 1857 the United States produced 12 barrels, or about 500 gallons, whilst at the present time the world's annual production is 5000 million gallons, of which last year the United States produced 2300 million gallons, and Russia a still larger amount. The remaining 277 million gallons were produced by Austria, 87 ; Sumatra, 72 ; Java, 30 ; Canada, 29 ; Roumania, 24 ; India, 15 ; Japan, 8 ; Germany, 7 ; Peru, 3 ; and Italy, 1.

Colliery Accidents.—A. de Kappen has collated the accident statistics of various countries, and shows that in coal-mining in 1886 to 1890 the average proportion of fatal accidents was as follows :—

	Per 1000 Miners.
Germany	2·566
Russia	2·434
France	2·105
Great Britain	1·835
Belgium	1·754
Austria	1·548

The average in 1891 to 1895 was—

	Per 1000 Miners.
Russia	2·522
Germany	2·450
Austria	2·389
Belgium	1·665
France	1·532
Great Britain	1·526

* *Iron Age*, March 29, 1900, pp. 5-6.

† *Petroleum Review*, vol. ii. pp. 5, 35.

The Fleets of the World.—In a report* made on behalf of the North-Western group of the *Verein deutscher Eisen und Stahl Industrieller*, it is stated that the object of the report is to consider from a general point of view all the questions, whether commercial or otherwise, affecting the iron trade. After reviewing the legal points that have arisen with regard to the German iron industry during the year, and that of workmen's insurance, the report deals with the proposed increase of the German fleet. A quotation is given from a German source, showing the expenditure on their fleets by the various great Powers during the last three years. These were as follows in millions of marks (shillings):—

	1897.	1898.	1899.
United Kingdom . .	421	448	498
France	204	224	235
United States . . .	143	495	198
Russia	134	150	186
Germany	108	122	133

Some other points are also given, and then various statistics are appended in tabular form.

This same question of the German fleet in connection with the iron trade is dealt with more fully by Kollman† in an address to the *Eisenhütte Oberschlesien*. In this it is pointed out that the German imports and exports each increased by 50 per cent. in the eight years 1889 to 1897, although the value only increased by 17·8 per cent. Per inhabitant the value of the imports increased from 83·55 shillings to 90·53 shillings, and the exports from 66·57 to 70·46 shillings. In 1898 the numbers show large increases, being respectively 99·83 shillings for the imports and 73·60 for the exports. In 1897, 43·2 per cent. of the imports consisted of raw material, while 60·9 per cent. of the exports were manufactured articles. The greater part of the foreign trade of Germany is ocean-borne, and, the necessity for an adequate fleet is therefore drawn attention to. The various articles of the export trade of Germany are specially considered, and it is shown in how far these are dependent on ocean-borne transit. The following table is then given as representing the fighting strengths of the different nations in the year 1900:—

* *Stahl und Eisen*, vol. xx. pp. 185-202.

† *Ibid.*, pp. 203-207.

United Kingdom	1,001
France	466
Russia	280
United States	195
Japan	189
Italy	189
Germany	179
Austria	64

How this calculation is arrived at is not stated, but it is pointed out that the United Kingdom, with a fighting strength of 1001, is not far behind the combined fighting strength, 1114, of France, Russia, Germany, and Italy. In another table the cost of the fleets is given per head of population as follows for the year 1899:—

	Total Number of Inhabitants.	Expenditure per Head.
	Millions.	Shillings.
United Kingdom	40·0	12·50
France	38·5	6·16
Germany	54·5	2·44
Russia	130·0	1·42
United States	72·8	2·71
Italy	31·3	2·77

The total cost per head for army, navy, and debt is stated to be 18·50 shillings for Germany, 33 shillings for the United Kingdom, and 41 shillings for France. No statements are given as to how the various statistics given have been arrived at. The following table represents, according to the author, the income and taxation of the inhabitants in the various countries, in addition to that previously given for the army, navy, and debt:—

Country.	Total Popu- lation.	Total Income.	Taxation per Head.
	Millions.	Milliards.	Shillings.
United Kingdom	40·0	25	24
Germany	54·5	21	16
France	38·5	20	32

The income is given in milliards (thousand million) of shillings.

The Railways of Germany, France, and the United Kingdom.—A comparative review of the railway systems of Germany, France, and the United Kingdom is given for 1897.* In that year

* *Stahl und Eisen*, vol. xx. p. 110.

these were of the following lengths, one kilometre being equal to 0·621 mile :—

	Kilometres.
Germany	47,119
France	41,569
United Kingdom	34,483

As regards area the ratios are :—

	Kilometres.
United Kingdom	11·2
Germany	8·7
France	7·8

for the same area, while for every 10,000 inhabitants the length is :—

	Kilometres.
France	10·8
Germany	8·8
United Kingdom	8·5

For each kilometre the capital employed was as follows :—

	£
Germany	12,642
France	15,732
United Kingdom	31,602

With regard to the equipment the engines in use were as follows :—

	Total Number.	Per 10 Kilometres.
United Kingdom	19,479	5·65
Germany	16,884	3·57
France	10,611	2·58

The carriages and waggons were as follows :—

<i>Passenger carriages—</i>	Total Number.	Per 10 Kilometres.
United Kingdom	44,053	12·77
Germany	33,664	7·11
France	27,179	6·62
<i>Goods waggons—</i>		
United Kingdom	664,833	192·8
Germany	361,508	76·4
France	279,534	68·1

This latter table is not in every respect perfect, in so far as it is not possible to ascertain fully the exact capacity of the goods waggons in question.

The number of passengers conveyed was as follows :—

	Millions.
United Kingdom	1030·4
Germany	692·5
France	396·7

while the goods conveyed amounted to :—

	Millions of Tons.
United Kingdom	380·4
Germany	285·6
France	113·5

Details are also given as to the relative earnings in the three countries from passenger and goods traffic, the order in which the countries stood being for both (1) United Kingdom, (2) Germany, and (3) France. The expenditure was as follows :—

	Per Cent.
United Kingdom	56·6
Germany	55·7
France	53·2

In the United Kingdom 35·5 journeys were made per inhabitant, while in Germany the number was only 13·4.

Duration of Coal Supplies.—Frech * deals with the duration of the coal supplies. He distinguishes four periods : (1) 100 to 200 years—Central France, Central Bohemia, the kingdom of Saxony, the province of Saxony, and the North of England ; (2) 250 years—other British coalfields, Waldenburg-Schatzlar coalfield, and the North of France ; (3) 600 to 800 years—Saarbrücken, Belgium, Aix-la-Chapelle, and Westphalia ; (4) more than 1000 years—Upper Silesia, Russian Poland, and Moravia.

* *Zeitschrift für Socialwissenschaft*, April 7, 1900.

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